

***Fiscal Year 2004 OU 7-13/14  
Environmental Monitoring  
Report for the Radioactive  
Waste Management Complex***

*L. Don Koeppen  
Gail L. Olson  
Alva M. Parsons  
Mitch A. Plummer  
Paul D. Ritter  
A. Jeffrey Sondrup*

**Idaho  
Completion  
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Bechtel BWXT Idaho, LLC

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**L. Don Koeppen  
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**Idaho Completion Project  
Idaho Falls, Idaho 83415**

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## **ABSTRACT**

This report summarizes data resulting from monitoring the air, waste zone, vadose zone, and aquifer in and around the Radioactive Waste Management Complex within the Idaho National Laboratory. This report is a joint publication of the Clean/Close Radioactive Waste Management Complex Project and the Waste Disposition Services Project. Results summarized here are used to satisfy several requirements and needs. The Waste Disposition Services Project uses the results to comply with requirements of U.S. Department of Energy Order 435.1, “Radioactive Waste Management,” Chapter IV, and the associated implementation manual and guidance, which require monitoring of low-level radioactive waste disposal facilities. The Clean/Close Radioactive Waste Management Complex Project uses the monitoring results to assess the nature and extent of contamination and to support risk assessment activities associated with Waste Area Group 7, which comprises the Radioactive Waste Management Complex.

Data from Fiscal Year 2004 are presented in detail, and historical aquifer data from Fiscal Years 1997–2004 are summarized to facilitate evaluation of temporal and spatial trends.





## EXECUTIVE SUMMARY

This report summarizes data resulting from monitoring the air, waste zone, vadose zone, and aquifer in and around the Radioactive Waste Management Complex (RWMC) and Subsurface Disposal Area (SDA) at the Idaho National Laboratory.

Contaminants consistently detected in soil moisture in the SDA vadose zone are summarized below:

- Uranium concentrations were above maximum contaminant levels (MCLs) and 1E-05 risk-based concentrations (RBCs) at various locations to depths of 69 m (227 ft), some with isotopic uranium ratios indicative of anthropogenic uranium slightly enriched in U-235.
- Technetium-99 was detected at two distinct locations of the SDA at depths to 27 m (88 ft). The concentration at one location is increasing and approaching the aquifer 1E-05 RBC.
- Nitrate concentrations were above MCLs in two areas of the SDA at depths to 28 m (92 ft).
- Low concentrations of tritium were found at various locations in the SDA to depths of 61 m (200 ft).
- Magnesium chloride brine constituents were detected to depths of approximately 122 m (400 ft), and some brine constituents may have reached the aquifer.
- Fluoride concentrations were above MCLs near Pad A at depths to 4.4 m (14.3 ft), with concentrations gradually increasing.

Contaminants detected in the aquifer beneath the RWMC are summarized below:

- Elevated concentrations of carbon tetrachloride, toluene, and trichloroethene were detected in monitoring wells located east and southeast of the RWMC. Carbon tetrachloride concentrations regularly exceed the MCL in Well M7S.
- Chromium concentrations are elevated and steadily increasing in Wells M1SA, M6S, M11S, and M15S. The MCL was recently exceeded in Well M15S.
- Some chemical constituents of magnesium chloride brine or buried waste may have been detected in aquifer wells east and southeast of the RWMC.
- Neptunium-237 was detected in one sample from Well M11S at a concentration slightly above the method detection limit.
- Uranium-233/234 found in aquifer was mostly at background levels, although the maximum concentration (i.e., 2.08 pCi/L) was slightly above the upper background tolerance limit of 1.92 pCi/L.
- Uranium-235 concentrations in Wells M12S and M13S are gradually increasing, and an upward trend is evident.

- Tritium is consistently detected at low concentrations in RWMC wells located in the northeast corner of the SDA.

Organic contaminants were shown to be declining in the soil gas because of ongoing vapor vacuum extraction efforts in the vadose zone. Elevated concentrations of select anions and cations are widespread in the vadose zone and are mostly attributable to magnesium chloride brine applied to roads within the SDA as a dust suppressant between 1984 and 1993. Concentrations of some brine contaminants measured in Fiscal Year 2004 were very high and were detected in the SDA at depths to 126 m (413 ft). Nitrate, which is not associated with the brine, has been detected at relatively high and increasing concentrations at various locations around the SDA. Technetium-99, C-14, and tritium are detected regularly at one or more locations, but the detections do not correlate well with the disposal locations. Trends in uranium detections correlate with the disposal locations. Uranium concentrations at several locations in the SDA are significantly above background. Uranium above background was consistently detected at depths to about 30 m (100 ft), and was also observed in a lysimeter sample collected at 69 m (227 ft). Detections are sporadic for Am-241, Cs-137, Cl-36, I-129, Np-237, plutonium, and Sr-90. Soil-gas and atmospheric data collected near Soil Vault Rows 12 and 20 suggest that C-14 and H-3 are migrating from disposals of beryllium blocks and activated metal.

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## ACRONYMS

ABRA	Ancillary Basis for Risk Analysis of the Subsurface Disposal Area
bls	below land surface
BORAX	Boiling Water Reactor Experiment
CFR	<i>Code of Federal Regulations</i>
COC	contaminant of concern
COPC	contaminant of potential concern
CY	calendar year
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FFA/CO	<i>Federal Facility Agreement and Consent Order</i>
FY	fiscal year
GC/MS	gas chromatography and mass spectrometry
GSP	gas-sampling port
HDPE	high-density polyethylene
ICP/MS	inductively coupled plasma and mass spectrometry
INL	Idaho National Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
MCL	maximum contaminant level
MDA	minimum detectable activity
MDC	minimum detectable concentration
MS	matrix spike
MSD	matrix spike duplicate
OCVZ	organic contamination in the vadose zone
OU	operable unit
PA and CA	performance assessment and composite analysis

PCE	tetrachloroethene (tetrachloroethylene) (perchloroethylene)
RBC	risk-based concentration
RFP	Rocky Flats Plant
RI/FS	remedial investigation and feasibility study
RTC	Reactor Technology Complex
RWMC	Radioactive Waste Management Complex
SDA	Subsurface Disposal Area
SRPA	Snake River Plain Aquifer
SVR	soil vault row
TCA	trichloroethane
TCE	trichloroethene (trichloroethylene)
TRU	transuranic
USGS	U.S. Geological Survey
UTL	upper 95 percent tolerance level with 95 percent confidence
VOC	volatile organic compound
VVET	vapor vacuum extraction with treatment
WAG	waste area group

# **Fiscal Year 2004 OU 7-13/14 Environmental Monitoring Report for the Radioactive Waste Management Complex**

## **1. INTRODUCTION**

This report summarizes data resulting from monitoring the air, waste zone, vadose zone, and aquifer in and around the Radioactive Waste Management Complex (RWMC) within the Idaho National Laboratory (INL). This report is a joint publication of the Clean/Close RWMC Project and the Waste Disposition Services Project. Figure 1-1 provides a map showing the location of the RWMC at the INL.

Contaminant concentrations are monitored routinely within and around the RWMC in soil gas, soil moisture, and the Snake River Plain Aquifer (SRPA) to determine whether waste buried in the SDA is impacting the environment. In addition, special studies are conducted to determine whether contaminants can be detected in the atmosphere and other media. Results from these hydrological monitoring activities are used to assess the nature and extent of contamination in the Subsurface Disposal Area (SDA), within the RWMC, to support the Clean/Close RWMC Project and the performance assessment and composite analysis (PA and CA) for the Waste Disposition Services Project.

This report is a joint effort of the Clean/Close RWMC and Waste Disposition Services projects to compile environmental monitoring results for the RWMC from Fiscal Year (FY)<sup>a</sup> 1997 through FY 2004, with emphasis on recent results. Data before FY 2004 are presented to evaluate the presence or absence of contaminant trends.

### **1.1 Purpose and Scope**

Monitoring results summarized in this report are used to satisfy several requirements and project objectives. The Waste Disposition Services Project uses the results to comply with requirements of U.S. Department of Energy (DOE) Order 435.1, "Radioactive Waste Management," Chapter IV, and the associated implementation manual and guidance, which require monitoring of low-level radioactive waste disposal facilities. In particular, the following requirements of DOE Order 435.1 must be addressed:

- Site-specific PA and CA will be used to determine the media, locations, radionuclides, and other substances to be monitored.
- The environmental monitoring program will be designed to include measuring and evaluating releases and migration of radionuclides.
- The environmental monitoring program will be capable of detecting changing trends in performance to allow application of necessary corrective action before exceeding the performance assessment objectives (i.e., action levels). The performance assessment objectives for FY 2004 are discussed and compared with monitoring results in the Waste Disposition Services Project annual review.

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a. Fiscal year, as it is used in this report, comprises the period between October 1 and September 30.

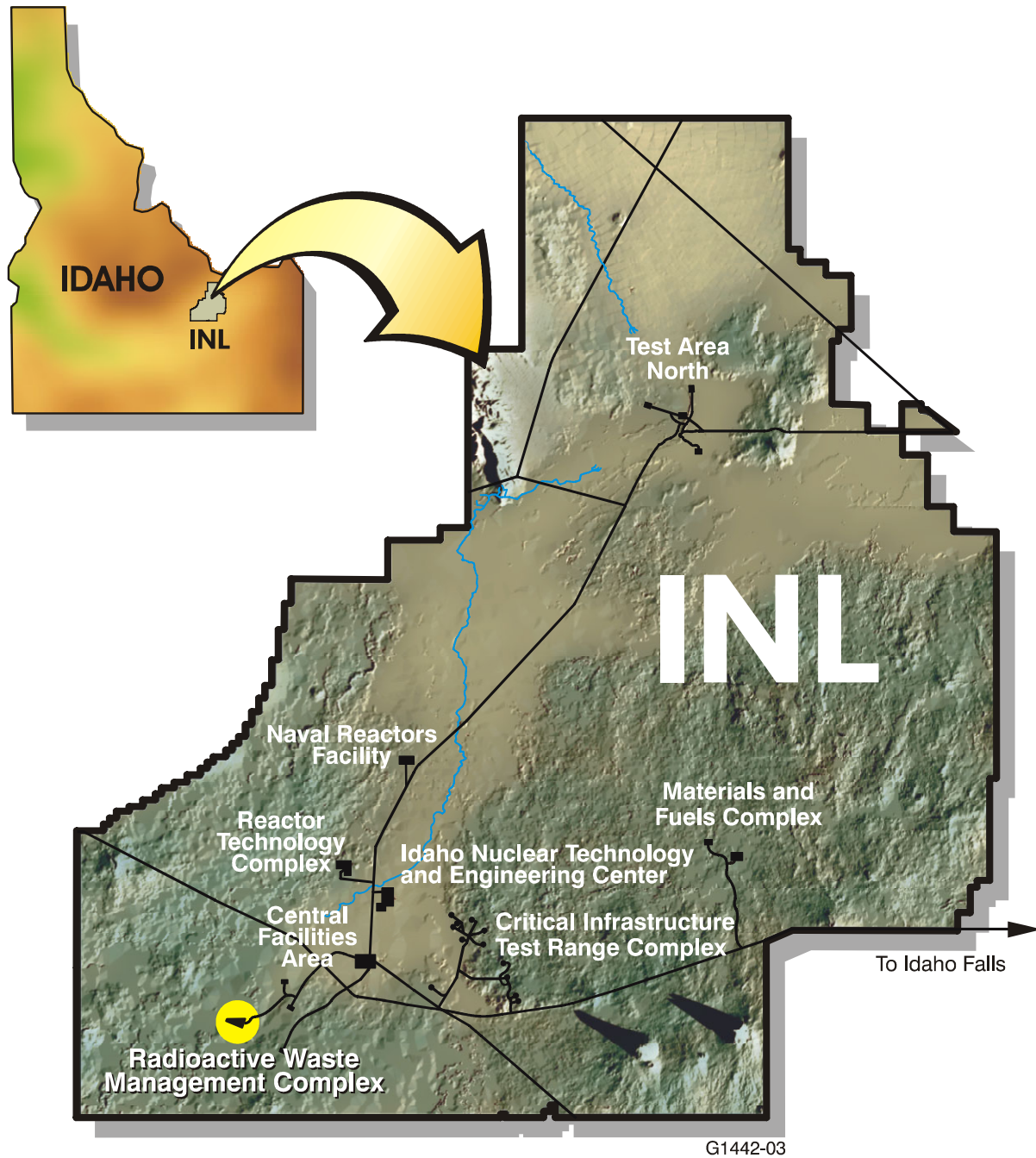


Figure 1-1. Map of the Idaho National Laboratory showing the Radioactive Waste Management Complex and other major program sites.

The Clean/Close RWMC Project uses monitoring results to support activities associated with the OU 7-13/14 comprehensive remedial investigation and feasibility study (RI/FS) for Waste Area Group (WAG)<sup>b</sup> 7, which comprises the RWMC. Operable Unit (OU) 7-13/14 (see Footnote b) is the designation for the comprehensive OU for WAG 7 recognized under the *Federal Facility Agreement and Consent Order for the Idaho National Engineering Laboratory* (FFA/CO) (DOE-ID 1991).

Environmental monitoring data are used to support the following OU 7-13/14 objectives:

- Assess the nature and extent of contamination being released from the waste zone
- Provide a baseline to establish monitoring requirements and support remedial decision making
- Provide modelers with reliable monitoring data for assessing uncertainty in modeling and associated risk assessment.

Monitoring priorities are established through collaborative efforts of the Clean/Close RWMC Project, the Waste Disposition Services Project, and other data users. Data required for the Waste Disposition Services Project are identified in the *Waste Disposition Services Project* description (McCarthy, Seitz, and Ritter 2001). Contaminants of concern (COCs) for assessing risk assessment are identified in the *Ancillary Basis for Risk Analysis of the Subsurface Disposal Area* (Holdren et al. 2002) and include radionuclides plus some organics and nitrates. Table 1-1 summarizes contaminants of interest for the two programs.

Table 1-1. Contaminants of interest to the Waste Disposition Services Project and Operable Unit 7-13/14.

Contaminants of Interest to the Performance Assessment and Composite Analysis Monitoring Program	Contaminants of Interest to the Operable Unit 7-13/14 Monitoring Program
C-14 <sup>a,b</sup>	C-14
Cl-36 <sup>a,b</sup>	Np-237
H-3 <sup>a,b</sup>	Pu-238
I-129 <sup>a,b</sup>	Sr-90
Np-237 <sup>a,b</sup>	Pu-239
U-233/234 <sup>a,b</sup>	Nb-94
U-235 <sup>a</sup>	Pu-240
U-238 <sup>a,b</sup>	Tc-99
Sr-90 <sup>a</sup>	Am-241
Ra-226 <sup>a</sup>	I-129
Gross alpha <sup>a</sup>	Carbon tetrachloride
	U-233
	Methylene chloride
	U-234
	Nitrates
	U-235
	Tetrachloroethene
	U-236
	U-238

a. Required for aquifer monitoring.

b. Required for vadose zone monitoring.

## 1.2 Site Description

The RWMC covers 71.6 ha (177 acres) in the southwestern quadrant of the INL. This includes the administration area of approximately 8.9 ha (22 acres), the SDA (39.3 ha [97.1 acres]), and the Transuranic Storage Area (23.3 ha [57.5 acres]). Figure 1-2 provides a map of the RWMC showing the location of pits, trenches, and soil vaults in the SDA.

b. The FFA/CO lists 10 WAGs for the INEEL. Each WAG is subdivided into OUs. The RWMC is identified as WAG 7 and originally contained 14 OUs. Operable Unit 7-13 (transuranic pits and trenches RI/FS) and OU 7-14 (WAG 7 comprehensive RI/FS) were ultimately combined into the OU 7-13/14 comprehensive RI/FS for WAG 7.

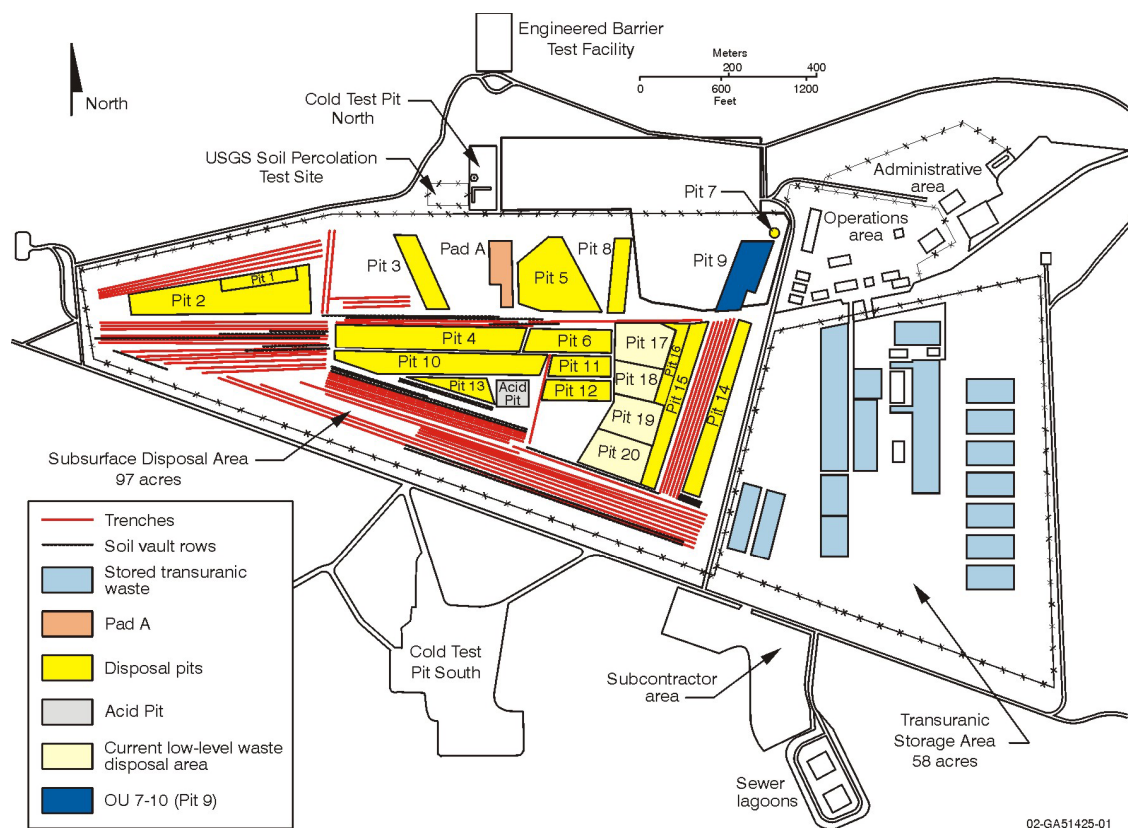


Figure 1-2. Waste disposal locations at the Radioactive Waste Management Complex.

In 1952, the SDA was established at 5.26 ha (13 acres) for disposal of solid radioactive waste. Burial of defense waste with transuranic (TRU) elements from the Rocky Flats Plant (RFP)<sup>c</sup> began in 1954; by 1957, the original SDA was nearly full. In 1958, the SDA was expanded to 35.6 ha (88 acres), which remained the same until 1988, when the security fence was relocated outside the dike surrounding the SDA, and the current size of 39.3 ha (97.1 acres) was established. Roughly 14.6 ha (36 acres) are waste disposal areas, and 25 ha (61 acres) comprise space between the pits, trenches, and dikes surrounding the overall area.

From 1952 to 1970, radioactive waste was buried in pits, trenches, and soil vault rows (SVRs) excavated into a veneer of surficial sediment. This sediment is underlain by a series of basaltic lava and sedimentary deposits. In 1970, the shallow burial of TRU waste ended. Since 1970, burial of low-level and other radioactive waste has continued, and TRU waste has been stored on aboveground asphalt pads in retrievable containers.

Figure 1-2 shows the layout of disposal units at the SDA. More detailed maps of the SDA, additional information on the environmental setting and history of disposal operations at the SDA, and the disposal inventory are presented in the *Ancillary Basis for Risk Analysis* (ABRA) (Holdren et al. 2002).

### 1.3 Report Organization

The remaining sections in this report are organized in the following manner:

c. The RFP is located 26 km (16 mi) northwest of Denver. In the mid-1990s, it was renamed the Rocky Flats Environmental Technology Site. In the late 1990s, it was again renamed, to its present name, the Rocky Flats Plant Closure Project.

- Section 2 provides information about the monitoring networks
- Section 3 provides radionuclide results in alphabetical order and by sampled media and depth
- Section 4 provides volatile organic compound (VOC) results in alphabetical order and by sampled media
- Section 5 provides inorganic analyses results in alphabetical order and by sampled media and depth
- Section 6 provides geohydrologic properties of interbed cores
- Section 7 summarizes information in the document
- Section 8 provides a list of the references cited in this document.





## **2. MONITORING AT TB RADIOACTIVE WASTE MANAGEMENT COMPLEX**

Environmental samples are collected routinely within and around the RWMC area and analyzed for a variety of radionuclide, inorganic, and organic contaminants. Samples are collected from the waste zone, the vadose zone, and the SRPA. Sampled media include soil moisture, soil vapor and gas, perched water, and water from the aquifer. Monitoring networks are described in this section. Routine monitoring of the vadose zone and aquifer beneath the RWMC in FY 2004 generated over 12,000 sample analyses results. Results for each contaminant are presented by monitoring zone: waste zone, vadose zone, and aquifer. Waste zone samples are collected from known pit or trench disposal locations within the SDA. Vadose zone samples are collected in areas that generally are adjacent to pits or trenches. Depth intervals from the vadose zone are listed below:

- 0–11 m (0–35 ft), not including samples collected from the waste zone. Vadose zone samples from this depth interval were located some distance from waste disposals, either between, beside, or away from pits or trenches in the SDA.
- 11–43 m (35–140 ft), which includes the A-B and B-C interbeds.
- Greater than 43 m (140 ft) deep, which includes the C-D interbed.

Summary tables and maps are presented for each contaminant, as appropriate. Time histories of monitoring results also are presented graphically to aid in understanding the evaluation discussions.

### **2.1 Soil-Moisture Sampling**

Soil-moisture samples are collected quarterly with suction lysimeters throughout the waste and vadose zones of the SDA. Installation of lysimeters in the SDA began in 1985 with the subsurface investigation program and continues today with the OU 7-13/14 monitoring network and Waste Disposition Services Project. A description of how the lysimeters were installed is provided in Section 2 of the ABRA.

Lysimeter samples are limited in volume. Some lysimeters yield only a few milliliters per sampling event, while others occasionally yield up to approximately 900 mL. Of note for vadose zone monitoring in FY 2004, soil-moisture sample volumes increased despite relatively dry weather. Increased volumes are attributable to improvements in sampling techniques. Several measures have been applied successfully, including upgrading surface hardware to minimize vacuum leaks, collecting samples at optimal sampling intervals, and applying a continuous vacuum for a longer period. Lysimeter-sample volumes were sufficient to complete most analyses identified on the vadose zone analytical priority list for OU 7-13/14. Because not all analyses of interest can be performed with the limited sample volume, analytical priorities were established for the lysimeter samples. The priorities were revised based on collaboration between the Clean/Close RWMC and Waste Disposition Services projects, and are provided in Table 2-1. Each set of quarterly samples were collected and analyzed in the order shown in Table-2-1.

Eighteen lysimeters were located in the waste zone at the beginning of FY 2004, and their locations were chosen based on a need to investigate specific focus areas. The waste zone lysimeters were placed from 1.5 to about 9 m (5 to about 30 ft) deep, and are in or just below the target waste, at the point of waste and underburden contact, or at the point of contact with the underlying basalt. Six waste zone lysimeters were abandoned in 2004 because they had not produced soil moisture samples since 2001. Reporting requirements of the FFA/CO (DOE-ID 1991) are not applicable to soil moisture samples

Table 2-1. Vadose zone analytical priorities for each quarter of Fiscal Year 2004.

Priority	Preservative	Container				
		None (field titration) (mL)	250-mL HDPE (mL)	500-mL HDPE (mL)	100-mL HDPE (mL)	100-mL HDPE (mL)
January–March						
C-14	None	—	50	—	—	—
Tc-99/gamma	Acid	—	—	50	—	—
U/Pu/Am	Acid	—	—	50	—	—
H-3	None	—	50	—	—	—
Cl-36	Acid	—	—	50	—	—
I-129	None	—	50	—	—	—
Np-237	Acid	—	—	50	—	—
Anions	Chill, 24 hours	—	—	—	25	—
Metals	Acid	—	—	—	—	25
April–June						
Anions	Chill, 24 hours	—	—	—	25	—
pH/Alkalinity	Field titrate	25	—	—	—	—
Metals	Acid	—	—	—	—	25
Cl-36	Acid	—	—	50	—	—
Tc-99	None	—	50	—	—	—
U/Pu/Am	Acid	—	—	50	—	—
C-14	None	—	50	—	—	—
July–September						
C-14	None	—	50	—	—	—
Gamma/Tc-99	Acid	—	—	50	—	—
U/Pu/Am	Acid	—	—	50	—	—
H-3	None	—	50	—	—	—
Cl-36	Acid	—	—	50	—	—
I-129	None	—	50	—	—	—
Np-237	Acid	—	—	50	—	—
Anions	Chill, 24 hours	—	—	—	25	—
Metals	Acid	—	—	—	—	25
October–December						
C-14	None	—	50	—	—	—
Gamma/Tc-99	Acid	—	—	50	—	—
U/Pu/Am	Acid	—	—	50	—	—
Anions	Chill, 24 hours	—	—	—	25	—
Metals	Acid	—	—	—	—	25
H-3	None	—	50	—	—	—
Cl-36	Acid	—	—	50	—	—
I-129	None	—	50	—	—	—
Np-237	Acid	—	—	50	—	—

HDPE = high-density polyethylene

HDPE = high-density polyethylene

collected in the waste zone. Locations of the focus areas are shown in Figure 2-1. The number of lysimeters per focus area is as follows:

- Uranium/Enriched Uranium Focus Area = 2
- Americium/Neptunium Focus Area = 1
- Organic Sludge Focus Area = 6
- Depleted Uranium Focus Area = 1
- Activated Metal Focus Area near SVR 12 = 2

Two of the waste zone lysimeters (741-08-L1 and 743-18-L2), located in Pits 10 and 4, respectively, yielded soil moisture samples during FY 2004 (see Figure 2-1). Only small sample volumes were obtained from each lysimeter; nevertheless, the volumes were sufficient to perform analysis for gamma-emitting radionuclides, plutonium isotopes, uranium isotopes, and Am-241. The results are discussed in Section 3.

Twenty-nine sampled lysimeters are in the shallow vadose zone (0–11 m [0–35 ft] deep) (see Figure 2-2), and 15 are in the intermediate vadose zone (11–43 m [35–140 ft] deep) (see Figure 2-3). Of the 29 shallow lysimeters sampled during FY 2004, only 11 produced soil-moisture samples on a regular basis; of the 15 intermediate depth lysimeters, 12 consistently produced samples during FY 2004. Unlike the waste zone lysimeters, the shallow vadose zone lysimeters are located adjacent to the waste in undisturbed sediments, not within disposal units or next to waste. The intermediate vadose zone lysimeters are located beneath the waste-zone depth, generally in basalt or interbed sediments.

At a depth greater than 43 m (140 ft), 18 lysimeters and three perched water wells provided samples during FY 2004 (see Figure 2-4). Wells USGS-092, 8802D, and D-10 are used to collect bailed perched water samples from above the 67-m (220-ft) interbed.

In 2004, 3 new wells were installed in the SDA, and 2 were installed outside the SDA. All five wells were instrumented with lysimeters. The depths of the newly installed lysimeters vary from 2.7–117 m (8.9–383 ft). Three lysimeter wells (R2004, R2005, and R2006) were installed on the east side of the SDA, with three lysimeters located in the 0–11 m (0–35 ft) depth interval (see Figure 2-2), four in the 11–43 m (35–140 ft) interval (see Figure 2-3), and three at depths greater than 43 m (140 ft) (see Figure 2-4). Also in 2004, Lysimeter Wells RWMC-1935 and RWMC-1936 were installed outside the SDA in the western and southwestern region of the RWMC to monitor the influence from the spreading areas and provide supplemental background monitoring for the vadose zone. These two lysimeter wells have one lysimeter located in the 0–11-m (0–35-ft) depth interval (see Figure 2-1), four in the 11–43-m (35–140-ft) interval (see Figure 2-2), and 14 at depths greater than 43 m (140 ft) (see Figure 2-3).

With the 10 lysimeters installed in FY 2003 in the SDA, 41 lysimeters are now in the deep vadose zone around the RWMC (i.e., 43–141 m [140–463 ft]), 19 of which are directly beneath the SDA, and 22 of which are outside the SDA. Of the 19 deep lysimeters in the SDA, 13 are located in the C-D interbed (approximately 73 m [240 ft] deep), and five are beneath the interbed at depths from 105–141 m (345–463 ft) below land surface (bls).

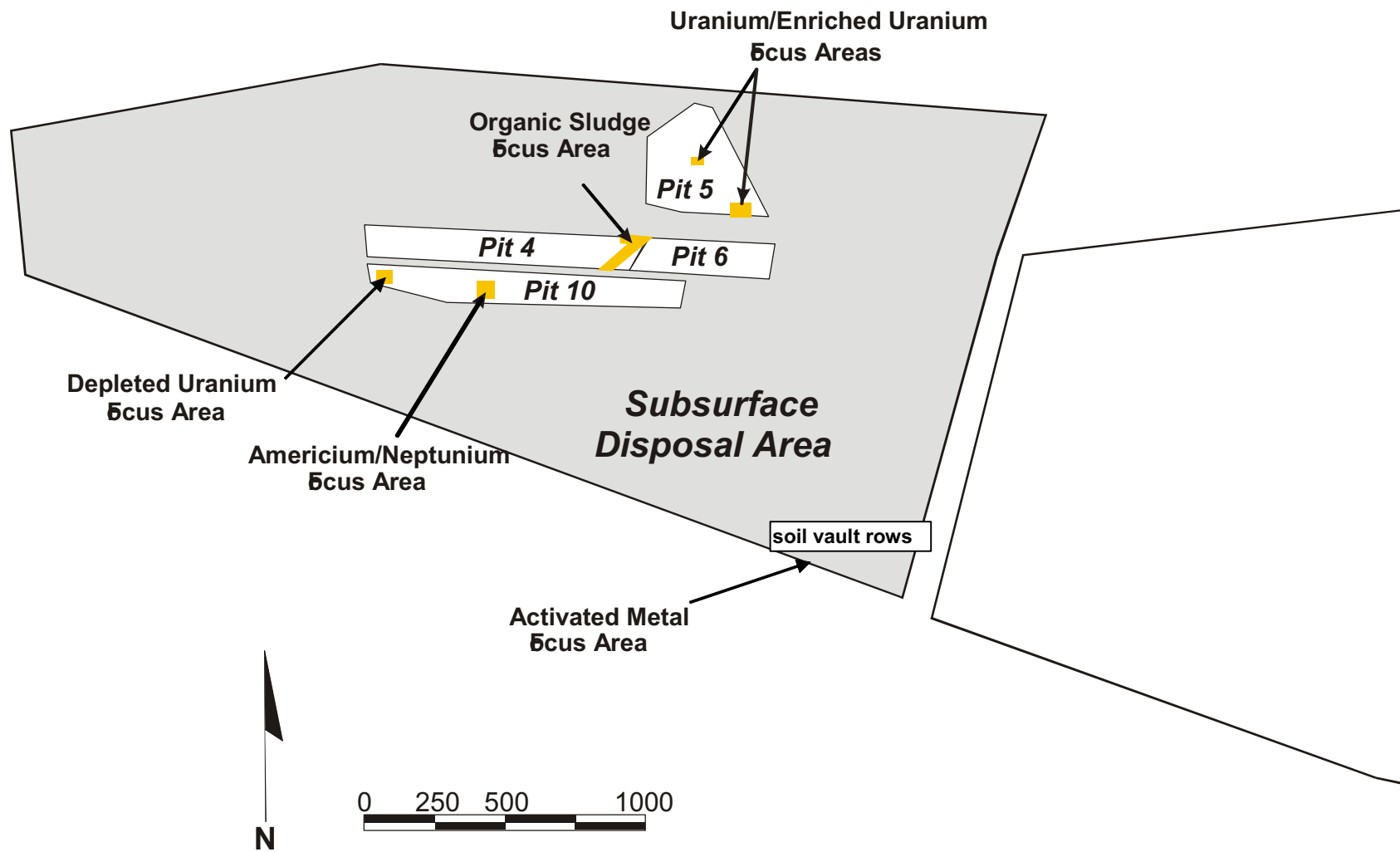


Figure 2-1. Location of focus areas at the Subsurface Disposal Area.

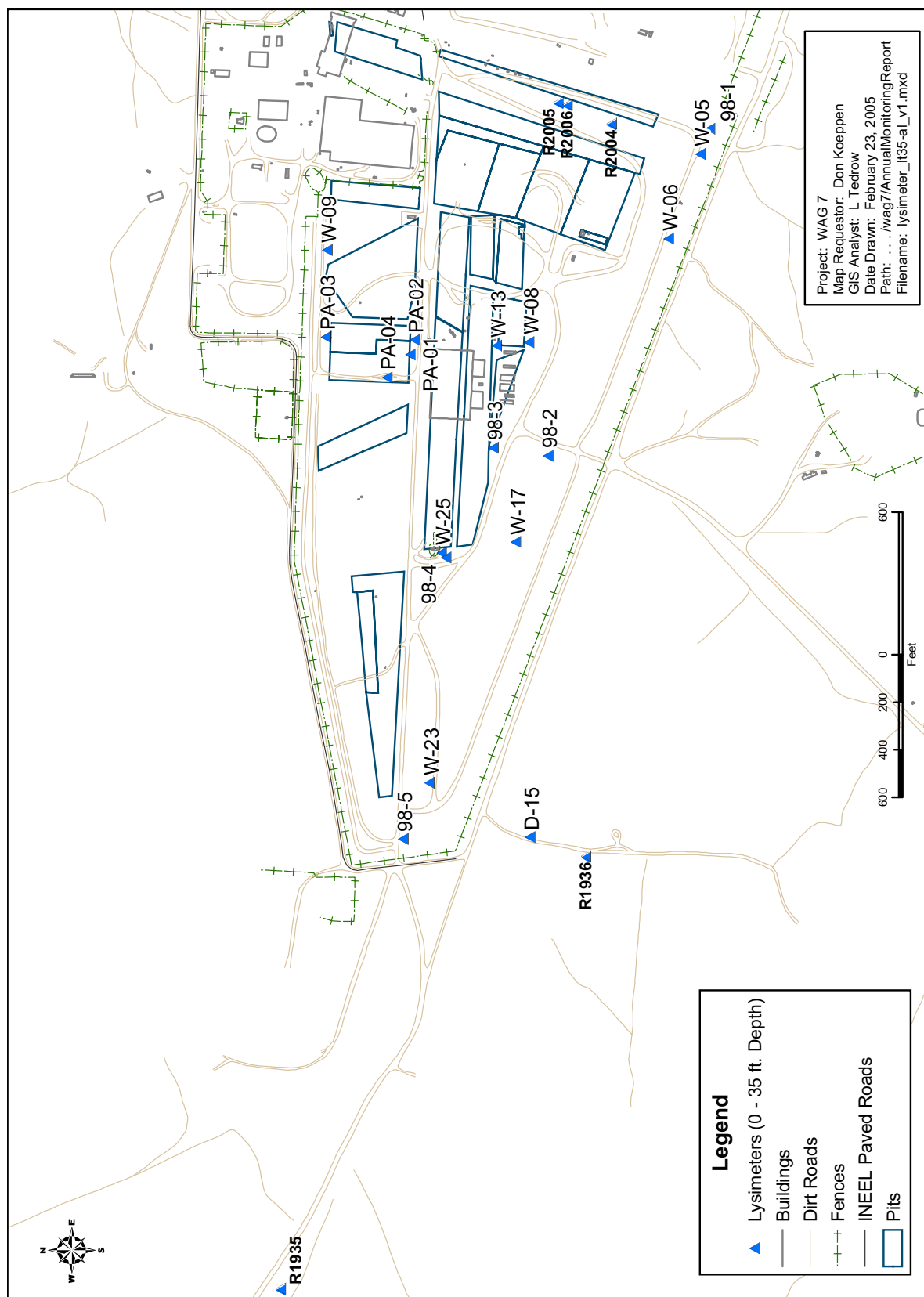


Figure 2-2. Locations of lysimeter monitoring wells in the 0–35-ft depth interval of the Subsurface Disposal Area.

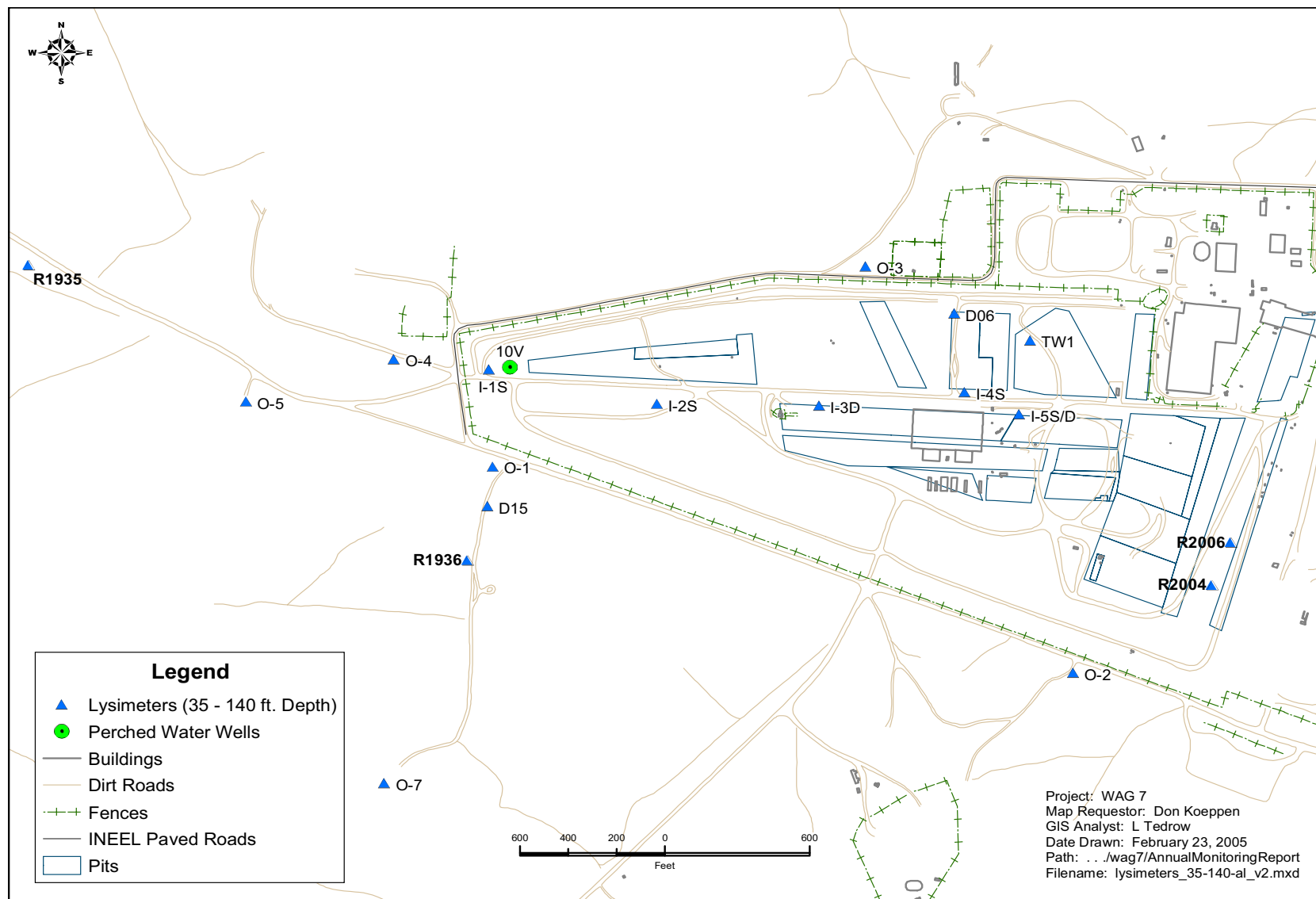


Figure 2-3. Locations of lysimeter monitoring wells in the 35–140-ft depth interval of the Subsurface Disposal Area.

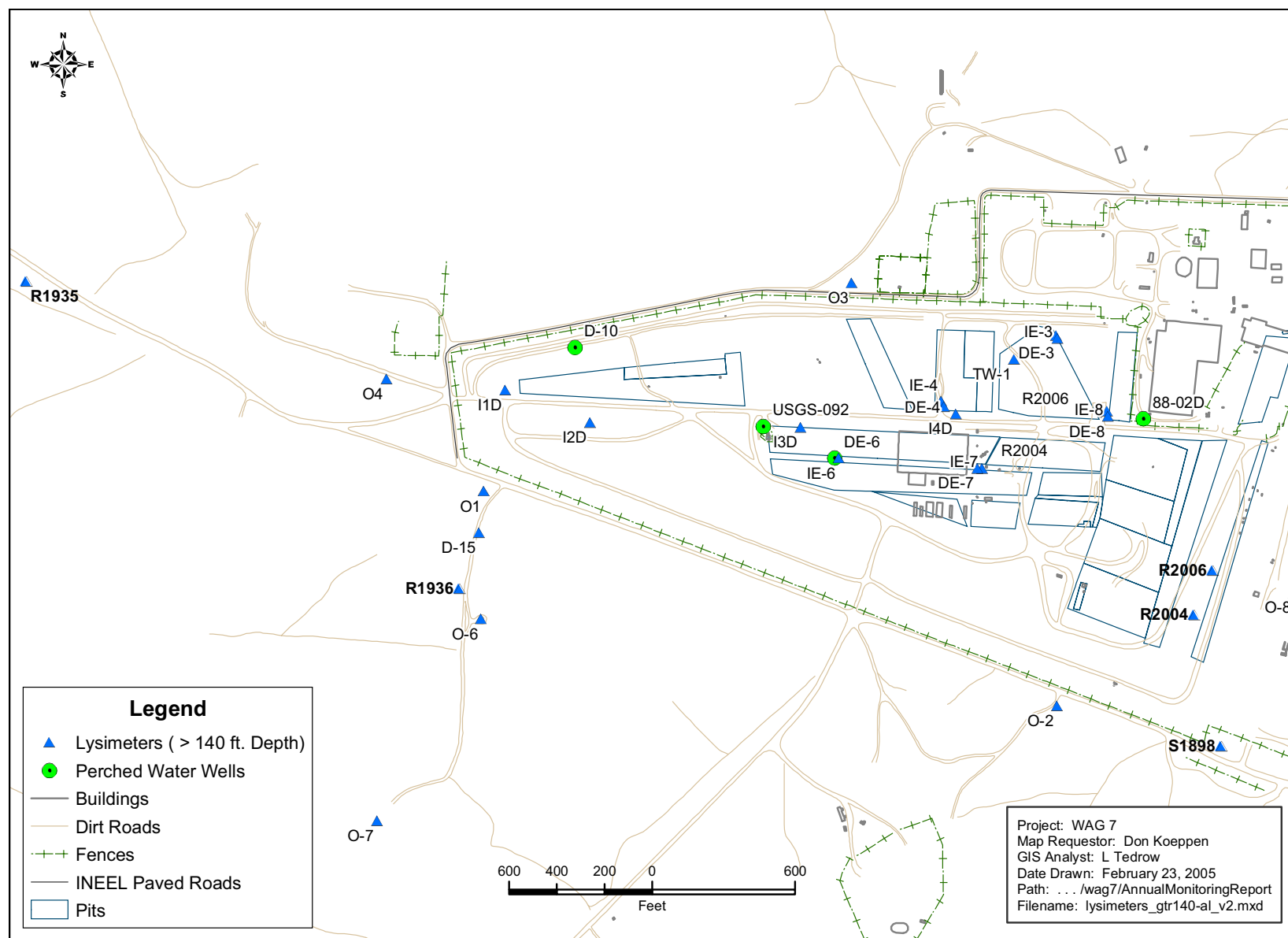


Figure 2-4. Locations of lysimeters and perched water monitoring wells deeper than the 140-ft-depth interval of the Subsurface Disposal Area.

## **2.2 Soil-Gas Sampling**

Soil-gas samples are collected routinely from the SDA subsurface for analysis of VOCs. Sample locations for VOCs and additional details are provided in the discussion of organic contaminant monitoring (see Section 4). Other soil-gas samples are collected from near buried beryllium reflector blocks to determine the extent of C-14 and H-3 releases. These sample locations and additional details are provided in the discussion of C-14 (Section 3.2) and H-3 (Section 3.4).

## **2.3 Aquifer Sampling**

Aquifer samples have been collected quarterly for many years; however, because years of monitoring data continued to show low and unchanging detection rates of contaminants, OU 7-13/14 proposed to the Agencies (i.e., U.S. Department of Energy, Idaho Department of Environmental Quality, and the U.S. Environmental Protection Agency) that monitoring frequency be reduced to semiannually. Consequently, starting in August 2004, aquifer monitoring was reduced to a semiannual frequency, as documented in the *Second Addendum to the Work Plan for the OU 7-13/14 Waste Area Group 7 Comprehensive Remedial Investigation/Feasibility Study*, (Holdren and Broomfield 2004). The U.S. Geological Survey (USGS) also collects aquifer samples at the RWMC, but the analytical data are not immediately available for use; therefore, the 2004 USGS data are not included here (except for organic contaminants).

Aquifer well locations are shown in Figure 2-5. Well M10S has been out of commission since the end of 2000. A replacement well (S1835) was drilled in 2003, but this well has a very low yield, and drilling mud used in its construction remains in the hole. Because of the high turbidity, elevated total organic carbon, and low yield, it was decided that samples would not be collected from this well for routine monitoring.

## **2.4 Interbed Sediment Sampling**

In addition to routine monitoring of the aquifer and vadose zone, an independent study was conducted in FY 2004 by Larry Hull, Joel Hubbell, and Cheryl Whitaker that involved sampling of the B-C and C-D sedimentary interbeds. Information concerning core sampling, analyses, and data evaluation presented in this section summarizes the results of that study.

Core samples were obtained from stored core material initially collected in the SDA by the Organic Contamination in the Vadose Zone (OCVZ) Project (i.e., OU 7-08) between November 2002 and March 2003. Each stored core tube was examined to ascertain whether appropriate samples could be obtained from the available material; the material was then described and photographed. This description was used to determine the core interval of interest for sampling. The following criteria were used for sampling:

1. Samples for radionuclide analyses were collected from the top of the core interval, unless it was apparent that the top was mixed or potentially contaminated
2. Samples for radionuclide analyses were collected at the juncture of a distinct coarse-to-fine sediment interface, when available
3. Samples for hydrologic analyses were near the top of interbed, if possible, as 15-cm (6-in.) long intact cores
4. Samples for geochemical analyses were located as close to hydrologic property samples as possible to obtain comparable data.



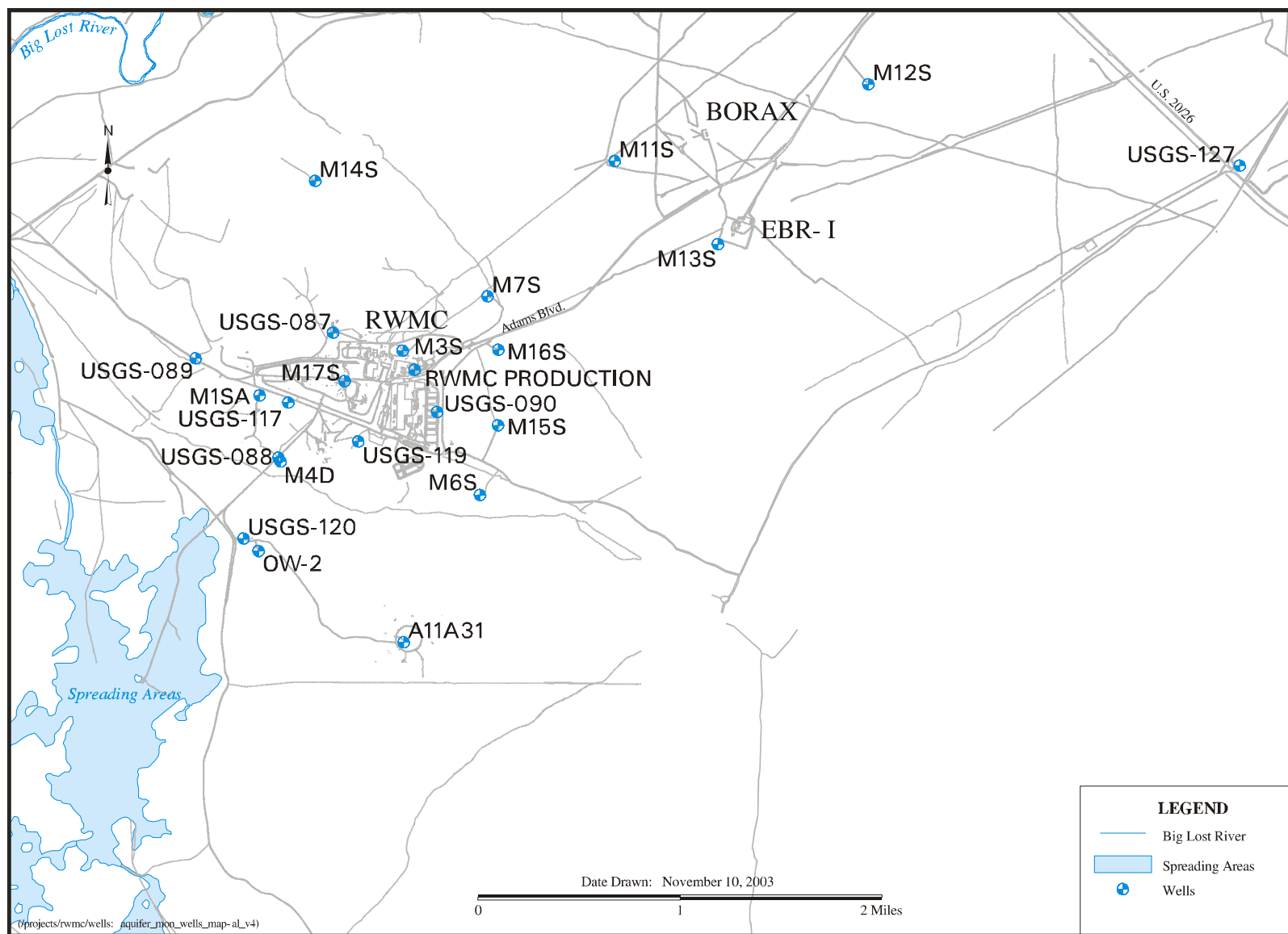


Figure 2-5. Locations of aquifer-monitoring wells at the Radioactive Waste Management Complex.

Samples were collected from cores obtained in areas known to contain significant inventories of contaminants. The wells from which cores were collected are located in the north-central portion of the SDA (see Figure 2-6). Core samples were analyzed for selected radionuclide contaminants, geochemical properties, and hydrologic properties. Sampled wells were Wells DE-3, DE-4, DE-6, DE-7, and DE-8 (see Figure 2-6). Radionuclide analysis included Tc-99, I-129, U-234, U-235, U-238, Np-237, Pu-238, Pu-239/240, and Am-241. Geochemical properties analyzed were mineralogy composition, exchangeable cations, cation exchange capacity, extractable iron, aluminum and manganese, and surface area. Hydrologic properties include hydraulic conductivity, porosity, moisture characteristics, particle size, water content, and dry bulk density. Radionuclide results are discussed and presented in Section 3, and the geochemical and hydraulic properties are presented in Section 6. No radionuclide contaminants were detected above soil background concentrations except for U-235 in Well DE-4. A discussion about the elevated U-235 concentration can be found in Section 3.12.2.4. Most geochemical and hydrologic properties compared with expected and previous interbed analysis results (see Section 6).

The purpose of the interbed core sampling and analysis was to provide hydrologic and geochemical data to compare with parameter values used in TETRAD fate and transport modeling for the remedial investigation and baseline risk assessment for OU 7-13/14. Geochemical properties were evaluated to test the assumption used in the TETRAD model of continuous, constant  $K_d$  values in interbeds for radionuclide retardation. Radionuclide concentration data acquired in this study are compared to previous sampling results, evaluated for consistency, and compared to radionuclide migration predicted by the TETRAD model. Data quality objectives for this project are discussed and documented in the *Sampling and Analysis Plan for Analyses of Hydrologic Properties, Geochemistry, and Radionuclides from Interbed Cores Drilled at the Radioactive Waste Management Complex* (Whitaker 2004). This information will provide a basis for supporting future risk management decisions for WAG 7 under the “Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA/Superfund)” (42 USC § 9601 et seq., 1980), as outlined in the FFA/CO. Also, these data will provide further information on the nature and extent of contamination migrating from the SDA.

## **2.5 Monitoring of Organic Contaminants**

Routine monitoring for organic contaminants is conducted at the SDA in the atmosphere, shallow and deep soil gas, the vadose zone, perched water, and the aquifer. Sample locations and additional details are provided in the discussion of organic contaminant monitoring (see Section 4).

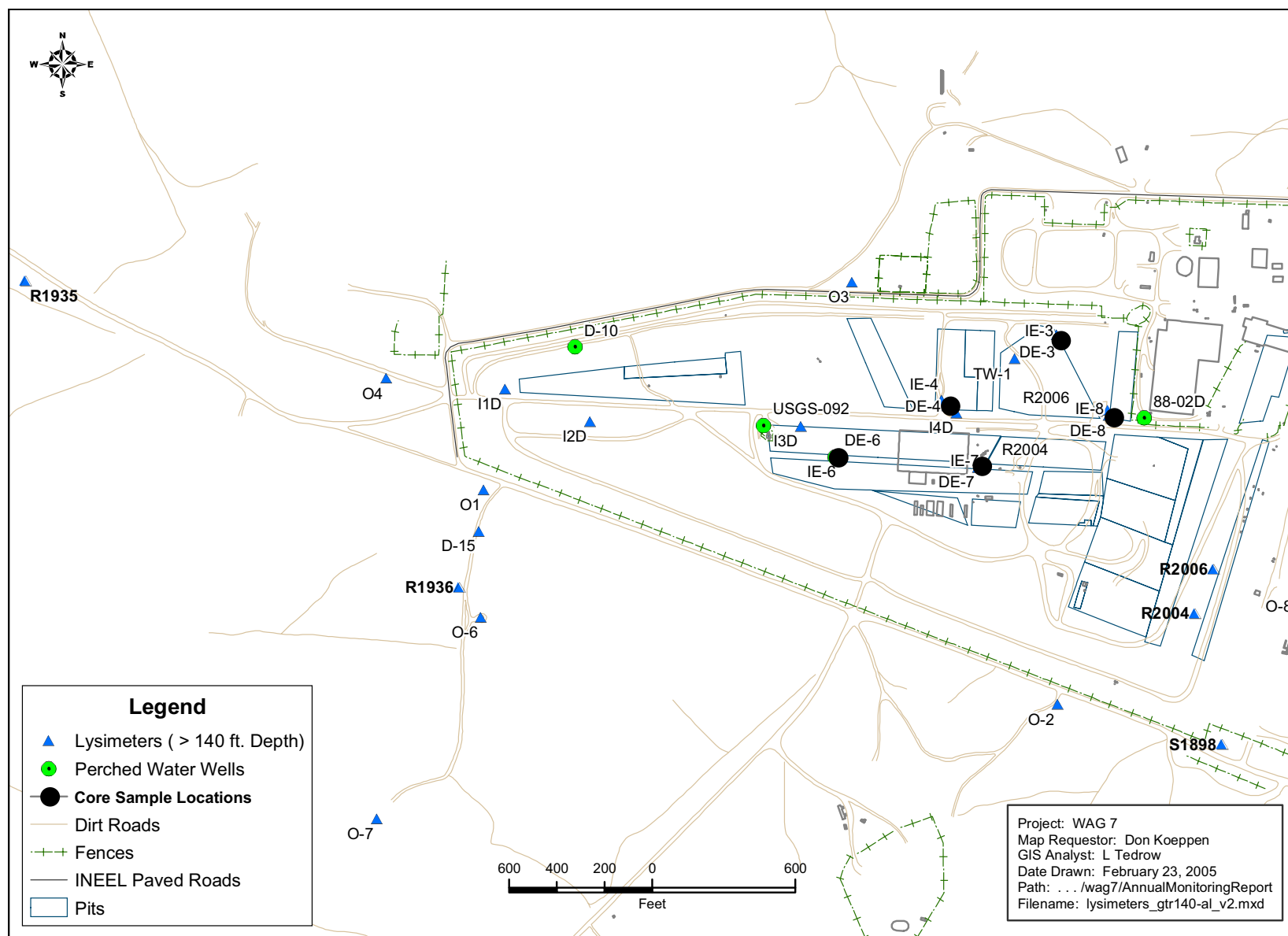


Figure 2-6. Well locations where interbed core samples were collected.



### 3. RADIONUCLIDE CONTAMINANTS IN THE ENVIRONMENT

Samples from the waste zone, vadose zone, and aquifer are collected routinely around the RWMC and are analyzed for a variety of radionuclides. Results from monitoring of radionuclides for FY 2004 are presented in this section. Historical data collected since FY 1997 also are summarized for perspective and to identify trends or the lack thereof.

Radionuclide concentrations greater than  $3\sigma$  and greater than the sample-specific minimum detectable concentration (MDC) are referred to throughout this section as “positive detections.” Concentrations greater than  $2\sigma$  and less than or equal to  $3\sigma$  are referred to as statistically positive detections.

When an actinide is detected at greater than  $2\sigma$  in an aquifer sample, the laboratory pulls another aliquot from the sample container and conducts another analysis of the sample to confirm the detection. If the second analysis fails to confirm the presence of the actinide, the result is referred to throughout this section as an “unconfirmed detection.” In FY 2003, the protocol for lysimeter samples was changed so that confirmation analyses were no longer conducted for actinide detections. The revised actinide protocol for lysimeters favors acquisition of data for various other priority analytes over confirmation of sporadic actinide detections.

#### 3.1 Americium-241

Approximately  $2.30\text{E}+05$  Ci of Am-241 was buried in the SDA (according to inventory estimates through 1999), and approximately  $3.81\text{E}+05$  Ci of Am-241 is expected to be generated over time through Pu-241 radioactive decay. The primary source of Am-241 and Np-237 in the SDA is RFP Series 741 sludge (i.e., first-stage wastewater sludge). An area in the central part of Pit 10 was identified as the Americium/Neptunium Focus Area for the OU 7-13/14 Probing Project, and a portion of Pit 4 is currently being excavated to retrieve Series 741 (and other) sludge, which contains Am-241 and other constituents.

##### 3.1.1 Waste Zone

Americium-241 analyses were performed on four samples collected from two waste zone lysimeters, with no positive detections. Quarterly attempts were made to collect samples from 18 waste zone lysimeters in the network, but only Lysimeters 741-08-L1 and 743-18-L2 yielded samples. Unfortunately, the low volumes obtained resulted in relatively high detection limits (i.e., 10–450 pCi/L).

##### 3.1.2 Vadose Zone

###### **3.1.2.1 Subsurface Soil Samples Collected While Drilling Lysimeter Well RWMC-2005.**

In April 2004, while drilling Lysimeter Well RWMC-2005 in the east end of the SDA (see Figure 2-3), radioactivity above background was detected in the drilling soil returns. Drilling was stopped and three separate soil samples were collected from these returns. The samples were analyzed for radioactive constituents, and Am-241 was detected in two of the samples (see Table 3-1).

Table 3-1. Americium-241 detections in Fiscal Year 2004 Subsurface Disposal Area vadose zone soil sample.

Radionuclide	Sample Date	Well ID	Lysimeter Depth (ft)	Sample Result $\pm 1\sigma$ (pCi/g)	MDC (pCi/g)	INL Soil Background UTL <sup>a</sup> (pCi/g)	Soil RBC <sup>b</sup> (pCi/g)
Am-241	04/26/04	RWMC2005	8.9	<b>0.022 <math>\pm</math> 0.007<sup>c</sup></b>	0.021	0.019	36.6
Am-241	04/26/04	RWMC2005	8.9	0.014 $\pm$ 0.004	0.009	0.019	36.6

a. INL surficial soil background 95% upper tolerance concentration limits for grab samples are not directly applicable to subsurface soils, but are provided here only as a basis for comparison. The surficial soil background tolerance limits were established in 1996 (Rood, Harris, and White 1996).

b. Calculated RBC for soil is equivalent to an increased cancer risk of 1E-05.

c. **Black bold font** indicates sample concentrations less than the RBC, but exceeding surficial soil background upper tolerance limit (see Footnote a). The laboratory performed duplicate analyses in accordance with routine internal quality control protocol. The duplicate analysis result for Am-241 was 0.039  $\pm$  0.007 pCi/g. Internal quality control test results, not normally reported in these summary tables, are included to provide additional evidence of the possible presence of Am-241 at this monitoring location.

INL = Idaho National Laboratory

MDC = minimum detectable concentration

RBC = risk-based concentration

UTL = upper 95% tolerance level with 95% confidence

**3.1.2.2 Lysimeter Samples at Depths of 0–35 ft.** Twenty-three Am-241 analyses were performed on soil-moisture samples collected from nine shallow lysimeters in and around the SDA in FY 2004 that resulted in one positive detection (see Table 3-2). The positive result did not exceed the calculated aquifer 1E-05 RBC of 4.76 pCi/L. The aquifer RBCs are not applicable to soil-moisture samples, but are used as a basis for comparison. The positive detection is suspect, because Am-241 has never been detected in Lysimeter Well W08, and the low measured concentration may be a false positive result. Most false positives in alpha spectroscopy are generally due to incomplete separation of the target radionuclide from the interfering radionuclides. Interference from natural Th-228 can cause false positive results of Am-241 (Kubilius et al. 2004). Results for Am-241 in the shallow vadose zone samples, since routine monitoring began in 1997, are summarized in Figure 3-1. Sporadic detections occur, but there are no apparent trends for Am-241 in the shallow lysimeters.

Table 3-2. Americium detection in FY 2004 Subsurface Disposal Area vadose zone soil-moisture samples from the 0–35-ft depth interval.

Radionuclide	Sample Date	Well: Lysimeter	Lysimeter Depth (ft)	Sample Result $\pm 1\sigma$ (pCi/L)	MDC (pCi/L)	Local Soil-Moisture Background <sup>a</sup> (pCi/L)	RBC <sup>b</sup> (pCi/L)
Am-241	01/26/04	W08:L13	11.3	<b>1.8 <math>\pm</math> 0.5<sup>c</sup></b>	1.0	0.0	4.76

a. The local soil moisture background concentration for Am-241 is essentially zero and defined as a nondetect (i.e., a result less than or equal to its MDA and less than or equal to three times its reported 1 $\sigma$  uncertainty). Local soil-moisture background concentrations are established with lysimeter samples regularly collected from the “O” and D15-series lysimeter wells located outside of the SDA.

b. RBC = 1E-05 for drinking water. The RBCs for the aquifer are provided here as a basis for comparison.

c. **Black bold font** indicates sample concentrations less than the RBC, but exceeding local soil-moisture background concentrations (see Footnote a).

MDA = minimum detectable activity

MDC = Minimum detectable concentration

RBC = risk-based concentration

SDA = Subsurface Disposal Area

		Americium-241 Radioactive Waste Management Complex Lysimeters (0–35 ft)															
FY	Qtr	98-1: L35	98-4: L38	98-5: L39	D15: DL07	PA01: L15	PA02: L16	PA03: L33	W05: L25	W06: L27	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
1997	1																
	2																
	3																
	4																
1998	1																
	2							4.2									
	3					8.8											
	4																
1999	1			0.8												0.8	
	2																
	3																
	4																
2000	1																
	2			0.3													
	3																
	4																
2001	1																
	2																
	3																
	4																
2002	1																
	2																
	3																
	4																
2003	1																
	2																
	3																
	4																
2004	1																
	2																
	3																
	4																
Key		Analysis was performed, but Am-241 was not detected.															
		Am-241 was detected (pCi/L).															
		Note 1: If more than one positive detection occurred in a single quarter, then only the highest concentration is listed.															
		Note 2: 1E-05 RBC = 4.76 pCi/L															
		FY = fiscal year															
		RBC = risk-based concentration															

Figure 3-1. Occurrences of americium-241 detections in the Radioactive Waste Management Complex shallow lysimeters since Fiscal Year 1997.

**3.1.2.3 Lysimeter Samples at Depths of 35–140 ft.** Thirty-six Am-241 analyses were performed on soil-moisture samples collected from 13 intermediate-depth lysimeters in and around the SDA in FY 2004, with three positive detections (see Table 3-3). These positive Am-241 detections are very suspect, because Am-241 has never been detected or confirmed to be present in these lysimeter wells and is known to be strongly sorbing and, therefore, unlikely at these depths. The Am-241 results may be false positives. Most false positives in alpha spectroscopy are generally due to incomplete chemical separation of the target radionuclide from the interfering radionuclides. Interference from natural Th-228 can cause false positive results of Am-241 (Kubilius et al. 2004). Results for the intermediate vadose zone samples, since routine monitoring began in 1997, are summarized in Figure 3-2. There are sporadic detections, but no apparent trends for Am-241 in the intermediate-depth lysimeters.

Table 3-3. Americium-241 detection in FY 2004 Subsurface Disposal Area vadose zone soil-moisture samples from the 35–140-ft depth interval.

Radionuclide	Sample Date	Well: Lysimeter	Lysimeter Depth (ft)	Sample Result $\pm 1\sigma$ (pCi/L)	MDC (pCi/L)	Local Soil-Moisture Background <sup>a</sup> (pCi/L)	RBC <sup>b</sup> (pCi/L)
Am-241	05/03/04	D06:DL01	88	<b>5.1 <math>\pm</math> 1.2<sup>c</sup></b>	1.9	0.0	4.76
Am-241	05/05/04	D15:DL06	97.9	<b>1.6 <math>\pm</math> 0.5<sup>d</sup></b>	0.8	0.0	4.76
Am-241	05/04/04	I-1S:DL09	101	<b>6.0 <math>\pm</math> 1.2<sup>c</sup></b>	1.0	0.0	4.76

a. The local soil moisture background concentration for Am-241 is effectively zero and defined as a nondetect (i.e., a result less than or equal to its MDC and less than or equal to three times its reported  $1\sigma$  uncertainty). Local soil-moisture background concentrations are established with lysimeter samples regularly collected from the “O” and D15-series lysimeter wells located outside of the SDA.

b. RBC = 1E-05 for drinking water. The RBCs for the aquifer are provided here as a basis of comparison.

c. **Red bold font** indicates sample concentrations that exceed the RBC (see Footnote b).

d. **Black bold font** indicates sample concentrations less than the RBC, but exceeding local soil-moisture background concentrations (see Footnote a).

MDC = minimum detectable concentration

RBC = risk-based concentration

SDA = Subsurface Disposal Area

**3.1.2.4 Lysimeter Samples at Depths Greater than 140 ft.** Forty-six Am-241 analyses were performed on perched water and lysimeter samples collected from three perched wells and 13 lysimeters in and around the SDA in FY 2004, resulting in one positive detection (see Table 3-4). Before this detection, and for three quarters thereafter, Am-241 was not detected at this depth interval in any perched water or vadose zone samples collected around the RWMC. Results for the samples, since routine monitoring began in 1997, are summarized in Figure 3-3.

Table 3-4. Americium detection in FY 2004 Subsurface Disposal Area vadose zone soil moisture and perched water samples from depths greater than 140 ft.

Radionuclide	Sample Date	Well: Lysimeter	Lysimeter Depth (ft)	Sample Result $\pm 1\sigma$ (pCi/L)	MDC (pCi/L)	Local Soil-Moisture Background <sup>a</sup> (pCi/L)	RBC <sup>b</sup> (pCi/L)
Am-241	10/28/03	IE4:DL32	223	<b>30 <math>\pm</math> 2<sup>c</sup></b>	1.0	0.0	4.76

a. The local soil moisture background concentration for Am-241 is effectively zero and defined as a nondetect (i.e., a result less than or equal to its MDC and less than or equal to three times its reported  $1\sigma$  uncertainty). Local soil-moisture background concentrations are established with lysimeter samples regularly collected from the “O” and D15-series lysimeter wells located outside of the SDA.

b. RBC = 1E-05 for drinking water. The RBCs for the aquifer are provided here as a basis of comparison.

c. **Red bold font** indicates sample concentrations that exceed the RBC (see Footnote b).

MDC = minimum detectable concentration

RBC = risk-based concentration

SDA = Subsurface Disposal Area



Americium-241 Radioactive Waste Management Complex Lysimeters (35–140 ft)															
FY	Qtr	D06: DL01	D06: DL02	D15: DL06	I-1S: DL09	I-2S: DL11	I-3S: DL13	I-4S: DL15	I-5S: DL16	O2: DL20	O3: DL22	O4: DL24	O5: DL25	O7 DL28	TW1: DL04
1997	1														
	2														
	3														
	4														
1998	1														
	2														
	3			2.4											
	4														
1999	1	0.8													
	2														
	3														
	4														
2000	1														
	2														1.9
	3														
	4														
2001	1														
	2														
	3														
	4														
2002	1														
	2														
	3														
	4														
2003	1														
	2														
	3														
	4														
2004	1														
	2														
	3	5.1		1.6	6.0										
	4														
Key		Analysis was performed, but Am-241 was not detected.													
		Am-241 was detected (pCi/L).													
If more than one positive detection occurred in a single quarter, then only the highest concentration is listed.															
Note: 1E-05 RBC = 4.76 pCi/L															
FY = fiscal year															
RBC = risk-based concentration															
RWMC = Radioactive Waste Management Complex															

Figure 3-2. Occurrences of americium-241 detections in intermediate-depth (35–140 ft) lysimeters since Fiscal Year 1997.

Americium-241 Radioactive Waste Management Complex Perched Water and Lysimeters (>140 ft)																							
FY	Qtr	8802D	DE4: DL33	DE7: DL36	DE7: DL37	D10	I2D: DL10	I3D: DL12	I4D: DL14	IE3: DL30	IE4: DL32	IE6: DL34	IE7: DL35	IE8: DL38	O2: DL19	O3: DL21	O4: DL23	O6: DL26	O7: DL27	O8: DL29	S1898: DL40	TW1: DL03	USGS-092
1997	1																						
	2																						
	3																						
	4																						
1998	1																						
	2																						
	3																						
	4																						
1999	1																						
	2																						
	3																						
	4																						
2000	1																						
	2																						
	3																						
	4																						
2001	1																						
	2																						
	3																						
	4																						
2002	1																						
	2																						
	3																						
	4																						
2003	1																						
	2																						
	3																						
	4																						
2004	1																						
	2																						
	3																						
	4																						
Key		Analysis was performed for Am-241, but none was detected.																					
		Am-241 was detected (pCi/L).																					
		If more than one positive detection occurred in a well in a single quarter, only the highest concentration is listed.																					
		Note: 1E-05 RBC = 4.76 pCi/L																					
		FY = fiscal year                      RWMC = Radioactive Waste Management Complex                      RBC = risk-based concentration																					

Figure 3-3. Occurrences of americium-241 detections in the deep-depth (greater than 140 ft) lysimeters since Fiscal Year 1997.

**3.1.2.5 Interbed Core Samples at Depths from 100–250 ft.** Thirteen Am-241 analyses were performed in FY 2004 on interbed core samples from the SDA, with no positive detections. The core samples originated from cores collected during OCVZ well-installation activities in FY 2003. Wells DE-3, DE-4, DE-6, DE-7, and DE-8 were sampled and analyzed for Am-241 (see Figure 2-6). Other core investigations have been conducted at the SDA, and Am-241 was detected previously. Between 1971 and 2000, 321 core samples were collected and analyzed for Am-241, with 34 positive detections. Detections in the vicinity of the interbeds are summarized in Table 3-5.

Table 3-5. Summary of americium-241 detections in Subsurface Disposal Area vadose zone core samples from 1971 to 2000.<sup>a</sup>

Interbed	Depth Interval (ft bls)	Concentration Range (pCi/g)	Am-241 Detection Rate (%)
B-C	98–113	0.006–0.908	18
C-D	226–238	0.016–0.033	2.8

a. Holdren et al. (2002).

### 3.1.3 Aquifer

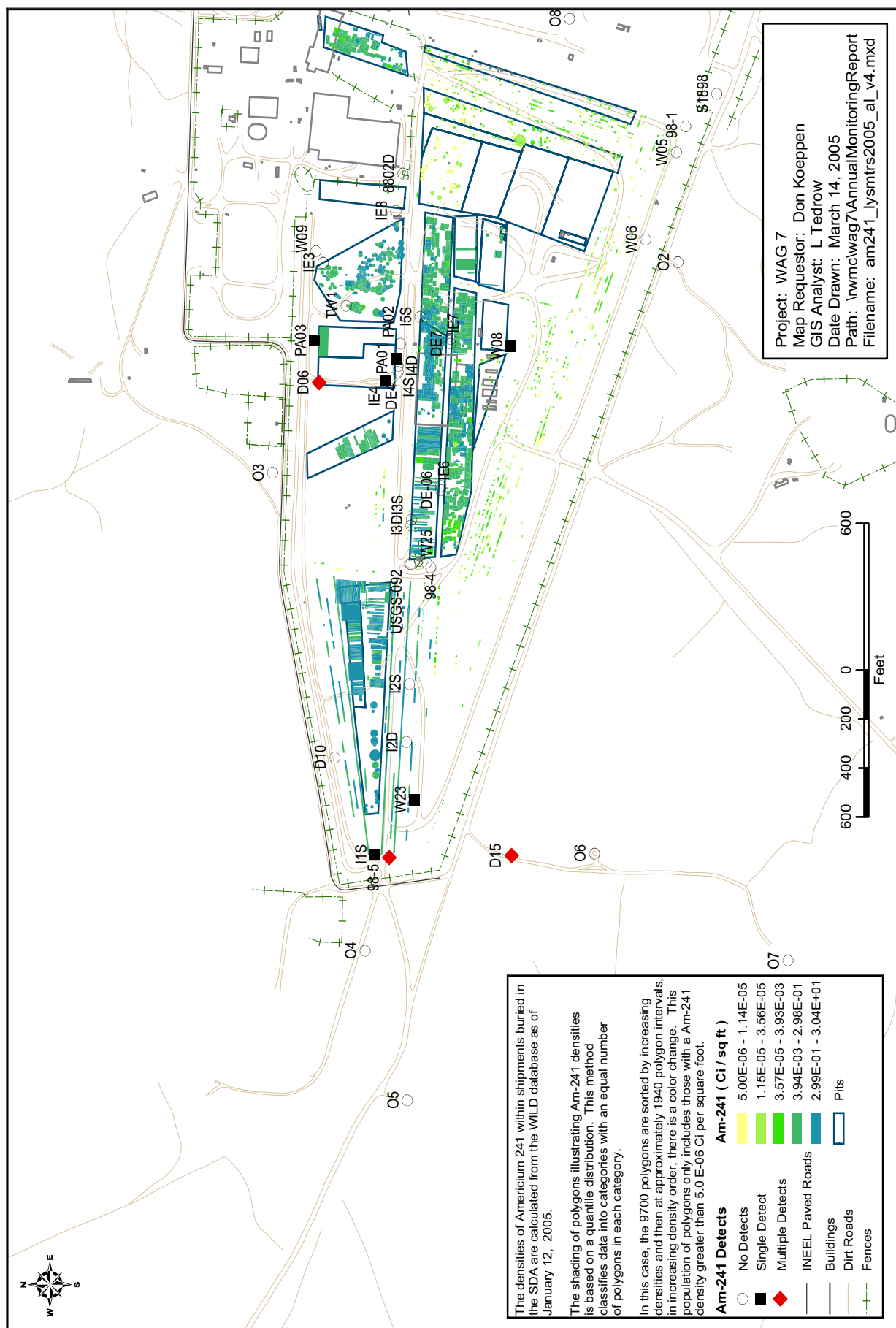
Forty-six Am-241 analyses were performed on aquifer samples collected from 15 monitoring wells in the vicinity of the RWMC in FY 2004, with no positive detections. At the end of 2004, the frequency at which the RWMC aquifer samples are collected was changed to biannually; thus, only data from the first three quarters of FY 2004 are available and shown in Figure 3-4. Historical results for the aquifer samples show sporadic detections but no evident trends. None of the positive detections exceeded the MCL of 15 pCi/L (total alpha) or the calculated aquifer 1E-05 RBC of 4.6 pCi/L.

### 3.1.4 Summary of Americium-241

Americium-241 was detected in five soil-moisture samples, but was not detected in any of the perched water, aquifer, or interbed core samples analyzed in FY 2004. Detections in the soil-moisture samples are very suspect because of the irregularity at which they occur in these particular monitoring wells, and the likelihood that the results are false positive because of interference from naturally occurring Th-228. Whether these Am-241 detections in vadose zone soil moisture are of concern or are indicative of the start of a trend will require continued monitoring. Historical detections in the vadose zone are depicted with the locations of waste disposals known to contain Am-241 (see Figure 3-5). Most of the mapped detections are one-time events that have not been substantiated with subsequent detections in more than 4 years. Two detections were made in Lysimeters 98-5:L39, D15:DL06, and D06:DL01 located near some mapped disposals on the west end of the SDA and near Pad A. There have been no positive detections found in samples from Lysimeter 98-5:L39 in the five sampled quarters since the second quarter of FY 2000. Americium-241 has not been detected in Lysimeters D06:DL01 and D15:DL06 since 1998; thus, it cannot be concluded that Am-241 is present at these locations in the vadose zone. Aquifer detections of Am-241 also are sporadic. Sporadic detections of Am-241 in the vadose zone and the aquifer since 1997 do not point to any evident spatial or temporal trends. Out of 902 Am-241 sample analyses performed on RWMC aquifer samples over the past 30 years, 12 positive detections have been associated with nine separate aquifer wells with only Well M1S exhibiting more than one Am-241 detection. Thus, more evidence and analytical data are available to support the absence of Am-241 in the aquifer than its presence.

			Americium-241 Radioactive Waste Management Complex Aquifer-Monitoring Wells														
FY	Qtr	A11 A31	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	M1S	M3S	M4D	M6S	M7S	OW-2	USGS- 127
1997	1																
	2																
	3																
	4																
1998	1																
	2																
	3																
	4																
1999	1																
	2																
	3																
	4																
2000	1																
	2																
	3																
	4																
2001	1																
	2																
	3																
	4																
2002	1																
	2																
	3																
	4																
2003	1																
	2																
	3																
	4																
2004	1																
	2																
	3																
Key		Analysis was performed, but Am-241 was not detected.															
		Am-241 was detected (pCi/L).															
		If more than one positive detection occurred in a single quarter, then only the highest concentration is listed.															
		Note: 1E-05 RBC = 4.76 pCi/L. MCL = 15 pCi/L total alpha. MCL = maximum contaminant level OOS = out of service. Well rendered inoperable after attempts at repairs were unsuccessful RBC = risk-based concentration															

Figure 3-4. Occurrences of americium-241 detections in aquifer samples around the Radioactive Waste Management Complex since Fiscal Year 1997.



## 3.2 Carbon-14

Carbon-14 is an activation product generated by nuclear operations. Most of the C-14 inventory in the SDA is contained in activated steel. Some of the disposal inventory is in the form of reactor core components, including beryllium reflector blocks and end pieces from reactor cores. Most of the remaining activity is in ion-exchange resins. Typical C-14-bearing waste was buried in the SVRs or trenches in the earlier years of operation. Approximately  $6.47\text{E}+02$  Ci of C-14 was buried in the SDA, according to inventory estimates through 1999.

Since 2001, C-14 in the vapor phase has been evaluated in detail at SVRs 12 and 20. In FY 2004, a study of C-14 throughout the SDA was conducted using samples from Organic Contamination in the Vadose Zone (OCVZ) monitoring ports. To simplify data presentation, C-14 results from liquid and core samples are presented first, followed by the vapor results from both the SVR and SDA-wide monitoring, followed by a summary that discusses all the data together.

This section presents the results from analyses of liquid samples collected from the waste zone, vadose zone, and the aquifer.

### 3.2.1 Waste Zone

Eighteen waste zone lysimeters were sampled every quarter in FY 2004 and Lysimeters 741-08-L1 and 743-18-L2 (located in Pits 10 and 4, respectively) were the only waste zone lysimeters to yield samples. Unfortunately, the volumes obtained were not sufficient for C-14 analysis.

### 3.2.2 Vadose Zone

#### 3.2.2.1 *Subsurface Soil Samples Collected While Drilling Lysimeter Well RWMC-2005.*

In April 2004, while drilling Lysimeter Well RWMC-2005 in the east end of the SDA (see Figure 2-3), radioactivity above background was detected in the drilling soil returns. Drilling was stopped, and three separate soil samples were collected from these returns. The samples were analyzed for C-14, and none was detected.

**3.2.2.2 *Lysimeter Samples at Depths of 0–35 ft.*** Twenty-eight C-14 analyses were performed on soil-moisture samples collected from 12 shallow lysimeters in and around the SDA in FY 2004, with two positive detections from lysimeter samples PA01 and LYS-1 (see Table 3-6). Lysimeter PA01 does not have a prior history of positive C-14 detections, and the result has not exceeded the  $1\text{E}-05$  RBC. Therefore, the detection is irregular with no required action, but will continue to be monitored. Carbon-14 was detected at high concentrations in the sample collected from Lysimeter LYS-1:L41 in October 2003. This is the first time enough sample volume has been available from this lysimeter to analyze for C-14. The detection and measured concentration are not surprising because the lysimeter is located in the southeast corner of the SDA near buried beryllium. Significant amounts of C-14 and tritium are known to be migrating into the surrounding area from the highly radioactive beryllium blocks. There are concerns as to whether C-14 concentrations measured in soil-moisture samples are representative of the actual concentration in the vadose zone because the process of sampling soil moisture (i.e., vacuum) may cause a significant portion of C-14 to volatilize from the water sample; therefore, measured concentrations may be low. Lysimeter LYS-1:L41 was taken out of service in FY-2004 because it was located in the region impacted by grout when nearby beryllium blocks were grouted with paraffin in the fall of 2004. Results for C-14 in shallow vadose zone samples, since routine monitoring began in 1997, are summarized in Figure 3-6. Sporadic detections occur, but no apparent trends are exhibited in the shallow lysimeters.

Carbon-14 Radioactive Waste Management Complex Lysimeters (0–35 ft)																		
FY	Qtr	98-1: L35	98-4: L38	98-5: L39	D15: DL07	LYS-1: L41	PA01: L15	PA02: L16	PA03: L33	W05: L25	W06: L27	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
1997	1																	
	2																	
	3							16			11							
	4							19										
1998	1																	
	2																	
	3							22										
	4																	
1999	1																	
	2																	
	3		24					26										
	4																	
2000	1																	
	2																	
	3																	
	4	60*																
2001	1																	
	2																	
	3																	
	4																	
2002	1																	
	2																	
	3																	
	4																	
2003	1																	
	2																	
	3																	
	4																	
2004	1						4,350											
	2						OOS											
	3						OOS	82*										
	4						OOS											
Key		Analysis was performed, but C-14 was not detected.																
		C-14 was detected (pCi/L).																
		<p>If more than one positive detection occurred in a single quarter, then only the highest concentration is listed.</p> <p>* Indicates a positive detection that received a “J” qualifier flag because of a minor quality control anomaly.</p> <p>Note: 1E-05 RBC = 307 pCi/L</p> <p>OOS = out of service (impacted by grouting of beryllium block)</p> <p>RBC = risk-based concentration</p>																

Figure 3-6. Occurrences of carbon-14 detections in shallow lysimeters since Fiscal Year 1997.

Table 3-6. Carbon-14 detections in FY 2004 Subsurface Disposal Area vadose zone soil-moisture samples from the 0–35-ft depth interval.

Radionuclide	Sample Date	Well: Lysimeter	Lysimeter Depth (ft)	Sample Result $\pm 1\sigma$ (pCi/L)	MDC (pCi/L)	Local Soil-Moisture Background <sup>a</sup> (pCi/L)	RBC <sup>b</sup> (pCi/L)
C-14	10/27/03	LYS-1:L41	6.6	<b>4,350 <math>\pm</math> 116<sup>c</sup></b>	15	0.0	307
C-14	05/04/04	PA01:L15	14.3	<b>82 <math>\pm</math> 13<sub>J</sub><sup>d</sup></b>	46	0.0	307

a. The local soil moisture background concentration for C-14 is essentially zero and defined as a nondetect (i.e., a result less than or equal to its MDC and less than or equal to three times its reported  $1\sigma$  uncertainty). Local soil-moisture background concentrations are established with lysimeter samples regularly collected from the “O” and D15-series lysimeter wells located outside of the SDA.

b. RBC =  $1\text{E-}05$  for drinking water. The RBCs for the aquifer are provided here as a basis of comparison.

c. **Red bold font** indicates sample concentrations that exceed the RBC (see Footnote b).

d. **Black bold font** indicates sample concentrations less than the RBC, but exceeding local soil-moisture background concentrations (see Footnote a). The concentration value with a “J” subscript denotes that a “J” data validation qualifier flag was assigned. The “J” flag was assigned to the C-14 result because of an analytical quality control anomaly. The result is questionable but usable, but should only be used as an estimated quantity.

MDC = minimum detectable concentration

RBC = risk-based concentration

SDA = Subsurface Disposal Area

**3.2.2.3 Lysimeter Samples at Depths of 35–140 ft.** Thirty-six C-14 analyses were performed on soil-moisture samples collected from 13 lysimeters in and around the SDA in FY 2004, resulting in one positive detection (see Table 3-7). Results for C-14 in intermediate-depth vadose zone samples, since routine monitoring began in 1997, are summarized in Figure 3-7. The positive result did not exceed the primary drinking water MCL of 2,000 pCi/L or the calculated aquifer  $1\text{E-}05$  RBC of 307 pCi/L. The MCL and aquifer RBC are not applicable to soil-moisture samples, but are used as a basis for comparison.

Table 3-7. Carbon-14 detections in FY 2004 Subsurface Disposal Area vadose zone soil-moisture samples from the 35–140-ft depth interval.

Radionuclide	Sample Date	Well: Lysimeter	Lysimeter Depth (ft)	Sample Result $\pm 1\sigma$ (pCi/L)	MDC (pCi/L)	Local Soil-Moisture Background <sup>a</sup> (pCi/L)	RBC <sup>b</sup> (pCi/L)
C-14	05/04/04	I-3S:DL13	93	<b>39 <math>\pm</math> 10<sub>J</sub><sup>c</sup></b>	38	0.0	307

a. The local soil moisture background concentration for C-14 is essentially zero and defined as a nondetect (i.e., a result less than or equal to its MDC and less than or equal to three times its reported  $1\sigma$  uncertainty). Local soil-moisture background concentrations are established with lysimeter samples regularly collected from the “O” and D15-series lysimeter wells located outside of the SDA.

b. RBC =  $1\text{E-}05$  for drinking water. The RBCs for the aquifer are provided here as a basis of comparison.

c. **Black bold font** indicates sample concentrations less than the RBC, but exceeding local soil-moisture background concentrations (see Footnote a). The concentration value with a “J” subscript denotes that a “J” data validation qualifier flag was assigned. The “J” flag was assigned to the C-14 result because of an analytical quality control anomaly. The result is questionable but usable, but should only be used as an estimated quantity.

MDC = minimum detectable concentration

RBC = risk-based concentration

SDA = Subsurface Disposal Area

**3.2.2.4 Lysimeter and Perched Water Samples at Depths Greater than 140 ft.** Sixty-one C-14 analyses were performed on perched water and deep-suction lysimeter samples collected from three perched water wells and 17 lysimeters in and around the SDA in FY 2004, resulting in one positive detection (see Table 3-8). Perched Water Well D-10 has not yielded water since 1996, so this is the first sample collected from that well since that time. Historical data also show this is the first time a sample



Carbon-14 Radioactive Waste Management Complex Lysimeters (35–140 ft)															
FY	Qtr	D06: DL01	D06: DL02	D15: DL06	I-1S: DL09	I-2S: DL11	I-3S: DL13	I-4S: DL15	I-5S: DL16	O2: DL20	O3: DL22	O4: DL24	O5: DL25	O7: DL28	TW1: DL04
1997	1														
	2														
	3														
	4														
1998	1														
	2														
	3														
	4														
1999	1														
	2														
	3														
	4														
2000	1														
	2														
	3														
	4														
2001	1														
	2														
	3														
	4														
2002	1														
	2														
	3														
	4														
2003	1														
	2														
	3														
	4														
2004	1														
	2														
	3														
	4														
Key		Analysis was performed for C-14, but none was detected.													
		C-14 was detected (pCi/L).													
		If more than one positive detection occurred in a well in a single quarter, then only the highest concentration is listed.													
		* Indicates a positive detection that received a “J” qualifier flag because of a minor quality control anomaly.													

Figure 3-7. Occurrences of carbon-14 detections in intermediate-depth (35–140 ft) lysimeters since Fiscal Year 1997.

from Well D-10 has been analyzed for C-14. It should be noted that tritium also was detected in Well D-10. The combination of tritium and C-14 suggests the possibility of irradiated beryllium blocks in the vicinity. Alternatively, some feature of the subsurface could facilitate transport of dual-phase contaminants to this location. Figure 3-8 provides a summary of results for C-14 in deep vadose zone samples since routine monitoring began in 1997.

Table 3-8. Carbon-14 detections in FY 2004 SDA vadose zone soil moisture and perched water samples from depths greater than 140 ft.

Radionuclide	Sample Date	Perched Water Well	Perched Water Depth (ft)	Sample Result $\pm 1\sigma$ (pCi/L)	MDC (pCi/L)	Aquifer Background <sup>a</sup> (pCi/L)	RBC <sup>b</sup> (pCi/L)
C-14	05/06/04	D-10	205.4	<b>185 <math>\pm</math> 16<sub>J</sub></b> <sup>c</sup>	45	0.0	307

a. For perched water, aquifer background values are applied, instead of local soil moisture values. The background concentration for C-14 in the aquifer is essentially zero and is defined as a nondetect (i.e., a result less than or equal to its MDC and less than or equal to three times its reported  $1\sigma$  uncertainty). Aquifer background concentrations established by the USGS are applied to perched water samples rather than local soil-moisture background concentrations.

b. RBC = 1E-05 for drinking water. The RBCs for the aquifer are provided here as a basis of comparison.

c. **Black bold font** indicates sample concentrations less than the RBC, but exceeding local soil-moisture background concentrations (see Footnote a). The concentration value with a “J” subscript denotes that a “J” data validation qualifier flag was assigned. The “J” flag was assigned to the C-14 result because of an analytical quality control anomaly. The result is questionable but usable, but should only be used as an estimated quantity.

MDC = minimum detectable concentration

RBC = risk-based concentration

SDA = Subsurface Disposal Area

USGS = U.S. Geological Survey

### 3.2.3 Aquifer

Forty-three C-14 analyses were performed on aquifer samples collected from 15 monitoring wells in the vicinity of the RWMC in FY 2004, with no detections. At the end of 2004, the frequency at which the RWMC aquifer was monitored changed to biannually; thus, only data from the first three quarters of FY 2004 are available and shown in Figure 3-9. Carbon-14 occurrences in aquifer samples, since 1997, are summarized in Figure 3-9. Results for the RWMC aquifer samples show sporadic detections but no evident trends. None of the positive detections exceeded the MCL of 2,000 pCi/L or the calculated aquifer 1E-05 RBC of 307 pCi/L.

### 3.2.4 Vapor Monitoring Results

Studies of C-14 and tritium in soil gas are ongoing in SVRs 12 and 20. Soil Vault Row 20 contains beryllium reflector blocks from the Advanced Test Reactor, which contained approximately 12 Ci of C-14 at the time of disposal. Routine<sup>d</sup> soil-gas sampling for C-14 began at SVR 20 during December 2001. During FY 2004, the OU 7-13/14 Early Action Beryllium Encapsulation Project was established to locate and grout beryllium buried in the SDA. Soil-gas sampling for C-14 was discontinued at SVR 20 after March 2004, because grouting operations required removal of the existing vapor sampling ports in early summer 2004. Two new wells (RWMC 2022 and RWMC 2023; aliases are SVR20-1 and SVR20-2) with vapor ports were installed at SVR 20 in August and November 2004 to sample soil gas near the grouted beryllium. Although data from these wells will not be directly comparable to the 1995–2003 dataset, the data will be evaluated to determine whether grouting has had an effect, and roughly, the degree of reduction of the source term.

d. Measurements of C-14 in soil gas were made at SVR 20 during 1996 and 1997; however, these were not routine in nature.

Carbon-14 Radioactive Waste Management Complex Perched Water and Lysimeters (>140 ft)																							
FY	Qtr	8802D	DE4: DL33	DE7: DL36	DE7: DL37	D10	I2D: DL10	I3D: DL12	I4D: DL14	IE3: DL30	IE4: DL32	IE6: DL34	IE7: DL35	IE8: DL38	O2: DL19	O3: DL21	O4: DL23	O6: DL26	O7: DL27	O8: DL29	S1898: DL40	TW1: DL03	USGS- 092
1997	1																						
	2																						
	3																						12
	4																						13
1998	1																						
	2	20																					20
	3																						
	4																						
1999	1																						
	2																						
	3																						
	4																						
2000	1																						
	2																						
	3																						
	4																						
2001	1																						
	2																						
	3																						
	4																						
2002	1																						
	2																						134
	3																						
	4																						
2003	1																						
	2																						
	3																						
	4																						
2004	1																						
	2																						
	3						185*																
	4																						
Key			Analysis was performed for C-14, but none was detected.																				
			C-14 was detected (pCi/L).																				
			If more than one positive detection occurred in a well in a single quarter, only the highest concentration is listed.																				
			* Indicates a positive detection that received a "J" qualifier flag because of a minor quality control anomaly.																				
			Note: 1E-05 RBC = 307 pCi/L																				
			RBC = risk-based concentration																				

Figure 3-8. Occurrences of carbon-14 detections in deep-depth (greater than 140 ft) lysimeters since Fiscal Year 1997.

Carbon-14 Radioactive Waste Management Complex Aquifer-monitoring Wells																	
FY	Qtr	AllA31	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	M1S	M3S	M4D	M6S	M7S	OW-2	USGS-127
1997	1																
	2																
	3																
	4																
1998	1																
	2																
	3																
	4				3.0	6.7											
1999	1																
	2				4.4						4.9						
	3																
	4						11										
2000	1													5.3	1.8		
	2																
	3																
	4				2.1	3.2	4.0				2.8	3.3			2.2		
2001	1																
	2		OOS														
	3		OOS	2.8	2.9	3.3											4.5
	4		OOS							42							
2002	1		OOS														
	2		OOS					4.5		7.5							
	3	3.1	OOS														
	4	7.1	OOS										3.5				
2003	1		OOS														
	2		OOS														
	3		OOS														
	4		OOS														
2004	1		OOS														
	2		OOS														
	3		OOS														
Key		Analysis was performed, but C-14 was not detected.															
		C-14 was detected (pCi/L).															
		If more than one positive detection occurred in a single quarter, then only the highest concentration is listed.															
		Note: MCL = 2,000 pCi/L. 1E-05 RBC = 307 pCi/L MCL = maximum contaminant level OOS = out of service. (Well was rendered inoperable after attempts at repairs were unsuccessful.) RBC = risk-based concentration															

Figure 3-9. Occurrences of carbon-14 detections in the aquifer-monitoring wells since Fiscal Year 1997.

Soil Vault Row 12, also in the southeast corner of the SDA, is known to contain large amounts of C-14 because of numerous disposals of what is believed to be activated stainless steel. Information gathered through conversations with past and present INL staff (Salomon 2003) indicates that these disposals are probably highly irradiated stainless steel end pieces removed from Experimental Breeder Reactor II spent fuel elements. Spent fuel elements from Experimental Breeder Reactor II were sent to the Idaho Nuclear Technology and Engineering Center (INTEC) for processing after use. The stainless steel end pieces were physically separated from the fuel in underwater basins at the Chemical Processing Plant (now INTEC) facility, CPP-603, before uncontained disposal (in baskets, not sealed) at the RWMC. Ten shipments were sent from CPP-603 and placed in SVR 12. The rate of C-14 release from activated steel, presumably by corrosion, is being studied at SVR 12. Nine Type B probes with vapor ports were installed at SVR 12 in 2001, and the initial sampling was conducted in 2002.<sup>e</sup> Samples have been collected from all of the ports since 2002 until early summer, 2004, when all but three of these probes (i.e., SVR-12-3-VP1, -VP-2, and -VP-3) were removed from SVR 12 to facilitate grouting operations. Sampling for C-14 from the remaining ports resumed in September 2004.

**3.2.4.1 Vapor Results from Soil Vault Rows 12 and 20.** Samples have been collected quarterly from functioning vapor ports at SVRs 12 and 20 since 2001, except for the period when beryllium grouting operations precluded routine sampling. Sampling sites near SVRs 12 and 20 are shown in Figure 3-10. The C-14 samples are analyzed for C-14 or C-14-specific activity (i.e., C-14 activity per unit mass of total carbon). Carbon-14 results for the functioning probes at SVR 12 are shown in Table 3-9. Results for C-14 analyses indicate that the C-14-specific activity in SVR 12 samples is two to three orders of magnitude above the typical background concentration of C-14 (i.e., 6.5 pCi/g C). The concentration of tritium in soil gas near SVR 12 also was measured and determined to be less than 600 pCi/L and most likely less than 100 pCi/L (i.e., near background levels). The absence of tritium in the soil gas provides confidence that the C-14 originates from the activated stainless steel in SVR 12 rather than activated beryllium.<sup>f</sup> Further evidence that the C-14 is from steel may be developed by future sampling at SVR 12 after the beryllium is grouted. If there is no change in C-14 concentrations in the soil gas, it would indicate that the nearby activated beryllium does not contribute measurably to the C-14 concentration in the SVR 12 soil gas.

Specific activity of C-14 in CO<sub>2</sub> has been measured in grab samples of soil gas collected from the Gas Sampling Port (GSP) -1 ports. Results for soil-gas samples are summarized in Table 3-10. These results are for samples collected using caustic solutions in bubblers before FY 2000 and in Tedlar bags after FY 2000. The SVR 20-IPV-5-VP3 soil-gas-sampling port is located approximately 5 m (16 ft) from the beryllium waste, and the GSP-1 gas-sampling ports are located approximately 0.8–1 m (2.6–3 ft) from the waste. The specific activity of C-14 in CO<sub>2</sub> is an approximate factor of 3 less at the more distant location, based on samples from both ports taken November 15, 2001, and August 23, 2002.

**3.2.4.2 Carbon-14 Results from Vapor Sampling Across the Subsurface Disposal Area.** The distribution of volatile C-14 in the vadose zone at the RWMC was examined in FY 2004. Vapor samples were collected from existing OCVZ monitoring ports at depths from 11–51 m (35–166 ft) to evaluate vapor phase transport of C-14 in the vadose zone (see Table 3-11 and Figure 3-11). Samples were collected from the intermediate vadose zone to evaluate downward migration of C-14 near known beryllium block disposal locations.

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e. B. G. Schnitzler Letter to M. M. Garland, INL, August 21, 1995, "Radionuclide Inventories of Advanced Test Reactor Outer Shim Control Cylinder and Reflector Block Components," BGS-12-95.

f. L. Don Koeppen Personal Communication with Daniel Mahnami, ICP, February 2004: "The SVR 12 Type B vapor ports are approximately 210 ft from the nearest activated beryllium disposal location."

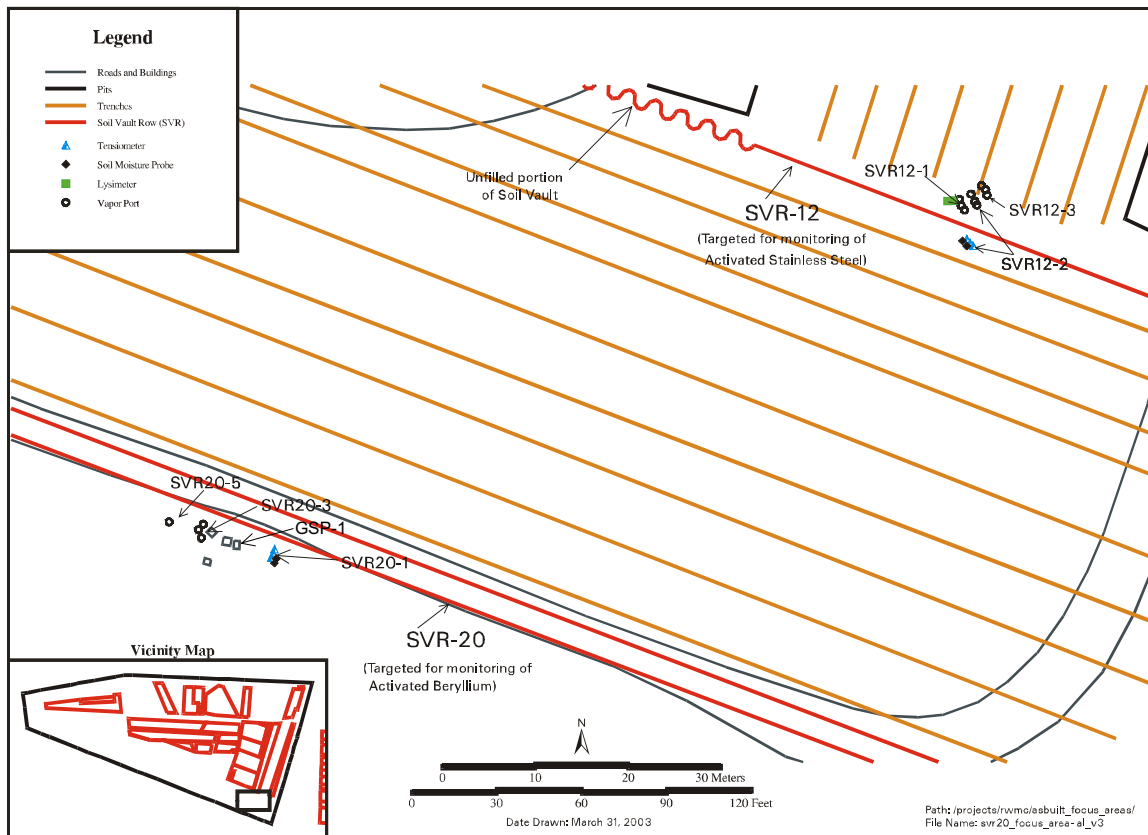


Figure 3-10. Vapor probes, tensiometers, lysimeters, and probes installed in the waste zone near or in Soil Vault Rows 12 and 20.

Table 3-9. Specific activity of carbon-14 (pCi [C-14]/g [C]) from vapor probes at Soil Vault Row 12.

Date	SVR-12-1-VP1	SVR-12-1-VP2	SVR-12-1-VP3	SVR-12-2-VP1	SVR-12-2-VP2	SVR-12-2-VP3	SVR-12-3-VP1	SVR-12-3-VP2	SVR-12-3-VP3
12/03/01	3,300	3,300	8,400	2,700	3,500	—	2,900	3,000	8,200
02/20/02	2,100	450	—	1,400	—	—	2,000	1,500	16,000
05/23/02	990	990	2,800	1,400	840	630	1,200	1,600	370
08/13/02	1,200	1,200	1,600	1,300	1,000	380	2,200	1,200	480
08/23/02	—	—	—	—	—	—	—	—	—
11/13/02	710	560	<MDC <sup>b</sup>	1,500	590	<MDC	1,100	680	<MDC
02/3/03	880	680	<MDC	970	—	480	1,100	680	<MDC
05/15/03	710	480	230	820	550	280	480	680	110
03/30/04	1,100	800	385	1,550	570	150	890	1,100	670
11/30/04	—	—	—	—	—	—	1,860	1,070	2,580

a. Relative uncertainty is greater than 33%. The relative uncertainty of the other results is typically 5–10%. In addition, the CO<sub>2</sub> concentrations in these samples are relatively low.

— = no sample was taken on that date

MDC = minimum detectable concentration

SVR = soil vault row

Table 3-10. Summary of carbon-14-specific activity (pCi [C-14]/g [C]) in CO<sub>2</sub> from soil-gas samples collected at Soil Vault Row 20 before grouting.

	GSP-1	GSP-1	GSP-1	SVR 20-IPV-5-VP3
Depth (m)	2.7	4.5	6.2	5.4
Date				
6/5/96	1.7E+04	—	2.3E+04	—
7/2/96	—	3.4E+04	2.5E+04	—
12/12/96	1.3E+05	4.2E+04	3.3E+04	—
11/12/97	4.4E+04	2.0E+04	1.2E+04	—
11/15/01	3.6E+05	1.6E+05	2.4E+05	8.3E+04
2/20/02	—	—	—	2.8E+04
5/2/02	1.7E+05	1.4E+05	1.3E+05	—
5/23/02	—	—	—	3.1E+04
8/23/02	1.3E+05	1.3E+05	1.4E+05	3.7E+04
11/13/02	—	—	—	2.4E+04
11/5/03	1.1E+05	1.4E+05	1.6E+05	4.1E+04 <sup>a</sup>
03/30/04	5.8E+04	6.4E+04	9.5E+04	—

a. In the analytical report, SVR-20-5-VP3 probe results apparently were switched with the SVR-12-1-VP3 results. The value reported here is considered the correct value for the sample.

GSP = gas-sampling port

SVR = soil vault row

Table 3-11. List of wells and vapor ports sampled for carbon-14 (June and July 2004) and carbon-14 concentrations in Radioactive Waste Management Complex vadose zone vapor samples.

Sample Vapor Port Location	Likely Source of Carbon-14	Sample Depth (ft)	Vapor Concentration (pCi/g)	Lysimeter Well Nearest to Vapor Port Location	Soil-Moisture Concentration at Lysimeter Well (pCi/L)
2V LINE 2	Trenches 52 and 57	147	0.357	O-8	No sample
2V LINE 4	Trenches 52 and 57	43	0.326	O-8	No sample
3V LINE 3	Migration from Pit 5 to lysimeters in Well TW-1	47	1.207	W09	ND
3V LINE 4	Migration from Pit 5 to lysimeters in Well TW-1	35	0.598	W09	ND
5E LINE 2	SVR 17 and Trench 58	50	1.204	I-2S	ND
5V LINE 3	Trench 28	49	0.513	None	No sample
8V LINE 3	SVR 17 and Trench 58	88	0.320	I-2S	ND
DO2 LINE 3	Migration from Pit 5 to lysimeters in Well TW-1	166	0.486	TW1	ND
DO2 LINE 5	Migration from Pit 5 to lysimeters in Well TW-1	100	0.485	TW1	ND
VVE10 LINE 2	SVR 20	138	0.358	M10S	ND

ND = not detected

SVR = soil vault row

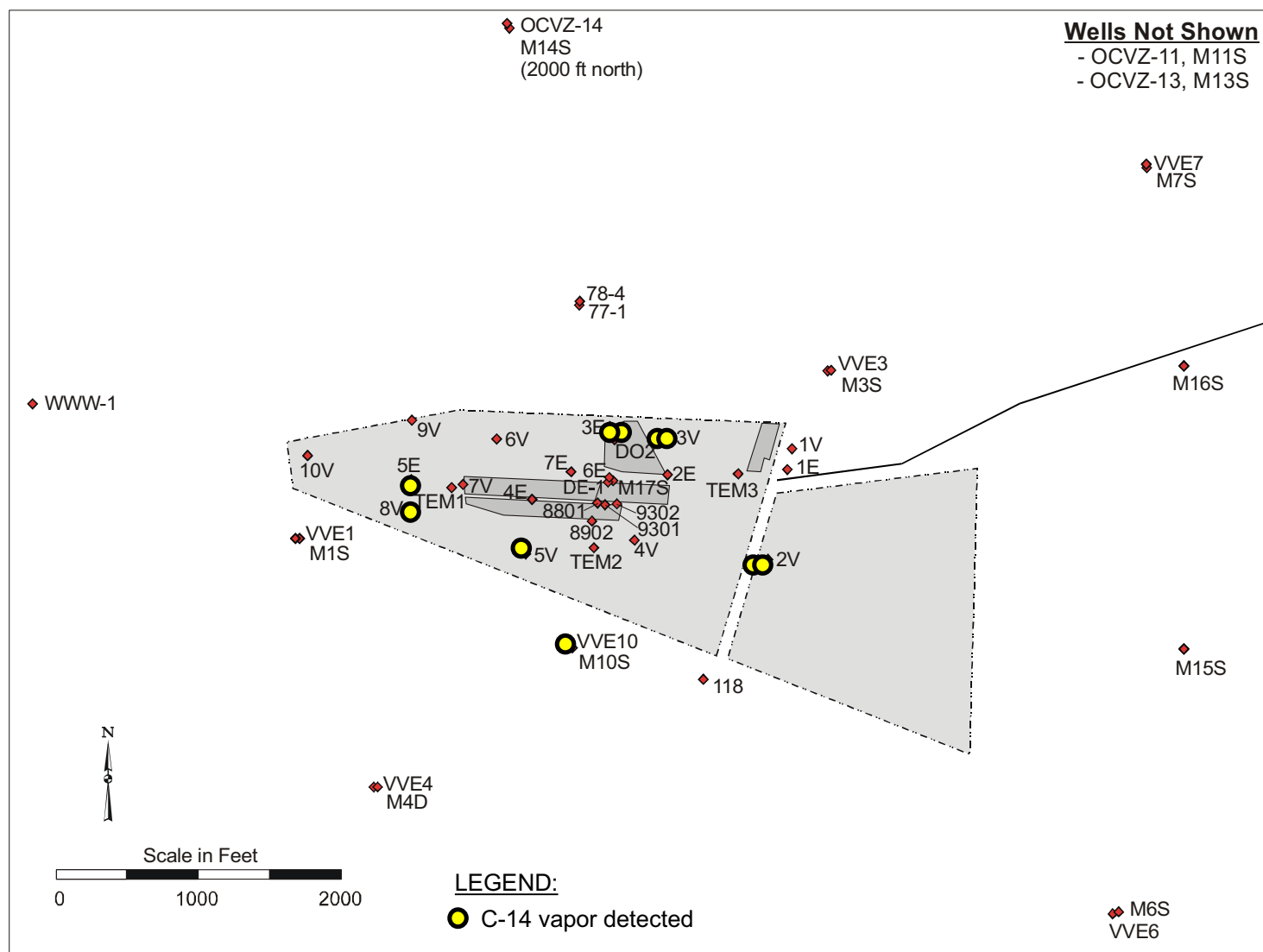


Figure 3-11. Map of the Radioactive Waste Management Complex showing the locations of Organic Contamination in the Vadose Zone Project wells, noting specifically where carbon-14 vapor was detected.



Carbon-14 vapor samples were collected at 10 locations around the SDA. Carbon-14 was detected at concentrations slightly above background levels in seven of the 10 gas-sampling wells. Carbon-14 was not detected at any depths below approximately 53 m (175 ft) (see Figure 3-12). The highest concentration was detected in Well 3V at 14 m (47 ft) deep.

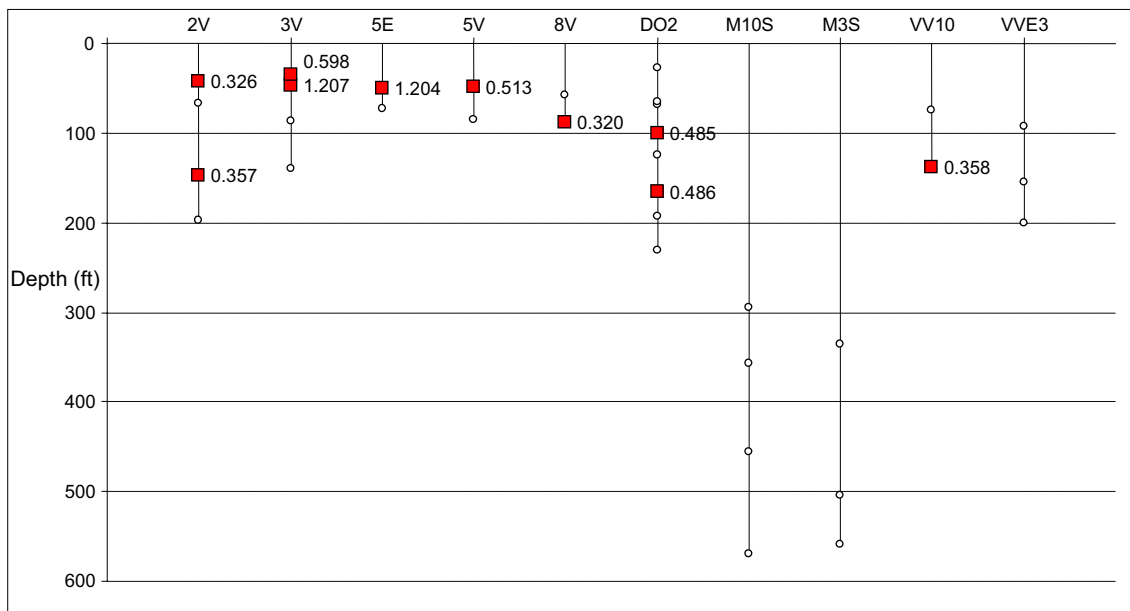


Figure 3-12. Carbon-14 gas-sampling locations and concentrations (pCi/g) of samples (shaded red squares) that exceeded background levels (0.3 pCi/g).

Vapor results are reported in Table 3-11 in units of C-14 activity per unit volume of gas collected (pCi/L), along with C-14 data from nearby lysimeter wells. As shown, C-14 was not detected in any of the soil-moisture samples, so numerical correlations between vapor and water results cannot be made for these samples.

### 3.2.5 Summary of Carbon-14

Table 3-12 shows maximum concentrations of C-14 in vadose zone soil moisture and perched water since FY 1997. Locations of detected C-14 in vadose zone samples are depicted in Figure 3-13 along with the known C-14 disposals. Historically, the most frequent C-14 detections occurred in samples from the PA02:L16 shallow lysimeter (see Figure 3-7) and from the USGS-092 perched water well (see Figure 3-9). Although no C-14 has been detected in Well USGS-092 since 2002, or in Well PA02 since 1999, repeated positive detections in Well USGS-92 between 1997 and 2002 suggest that C-14 has migrated to the 67-m (220-ft) perched water region beneath the RWMC (see Holdren et al. 2002, Section 4). Because of the volatile nature of C-14, there are concerns as to whether samples obtained by suction lysimeters (vacuum) are truly representative of the concentration actually in the vadose zone. It is possible that C-14 may be present at some lysimeter locations, but is volatilized during sample collection and yields either a nondetection or a biased-low concentration.

Carbon-14 was not detected in any of the RWMC aquifer-monitoring wells during FY 2004. Table 3-13 presents maximum concentrations of C-14 in RWMC aquifer wells since FY 1997. Detections are infrequent, and no discernible concentration trends exist at any of the monitoring-well locations.

Table 3-12. Summary of maximum concentrations of carbon-14 in vadose zone soil-moisture and perched water samples at the Radioactive Waste Management Complex from Fiscal Year 1997 through 2004.<sup>a</sup>

Sampling Range (ft bls)	Fiscal Year <sup>b</sup>	Maximum Concentration $\pm 1\sigma$ (pCi/L) <sup>c</sup>	Sample Location
Lysimeters 0–35 ft	1997	19 $\pm$ 4	PA02-L16
	1998	21.8 $\pm$ 1.9	PA02-L16
	1999	26 $\pm$ 5	PA02-L16
	2000	ND	Various <sup>d</sup>
	2001	NA	—
	2002	NA	—
	2003	ND	Various
	2004	4,350 $\pm$ 116	LYS-1:L41
Lysimeters 35–140 ft	1997	NA	—
	1998	ND	Various
	1999	NA	—
	2000	NA	—
	2001	NA	—
	2002	NA	—
	2003	46 $\pm$ 14	I2S-DL11
	2004	39 $\pm$ 10	I3S-DL13
Lysimeters >140 ft	1997	NA	—
	1998	NA	—
	1999	NA	—
	2000	NA	—
	2001	NA	—
	2002	NA	—
	2003	ND	Various
	2004	ND	Various
Perched water wells >140 ft	1997	13 $\pm$ 2	USGS-92
	1998	20 $\pm$ 4	USGS-92 and 8802D
	1999	ND	USGS-92
	2000	NA	—
	2001	NA	—
	2002	134 $\pm$ 38	USGS-92
	2003	ND	USGS-92
	2004	185 $\pm$ 16	D-10

a. MCL = 2,000 pCi/L

b. Fiscal year spans from October 1 to September 30 (e.g., Fiscal Year 1997 is October 1, 1996, to September 30, 1997).

c. NA = not analyzed ND = not detected

d. Various locations were sampled.

MCL = maximum contaminant level

USGS = United States Geological Survey

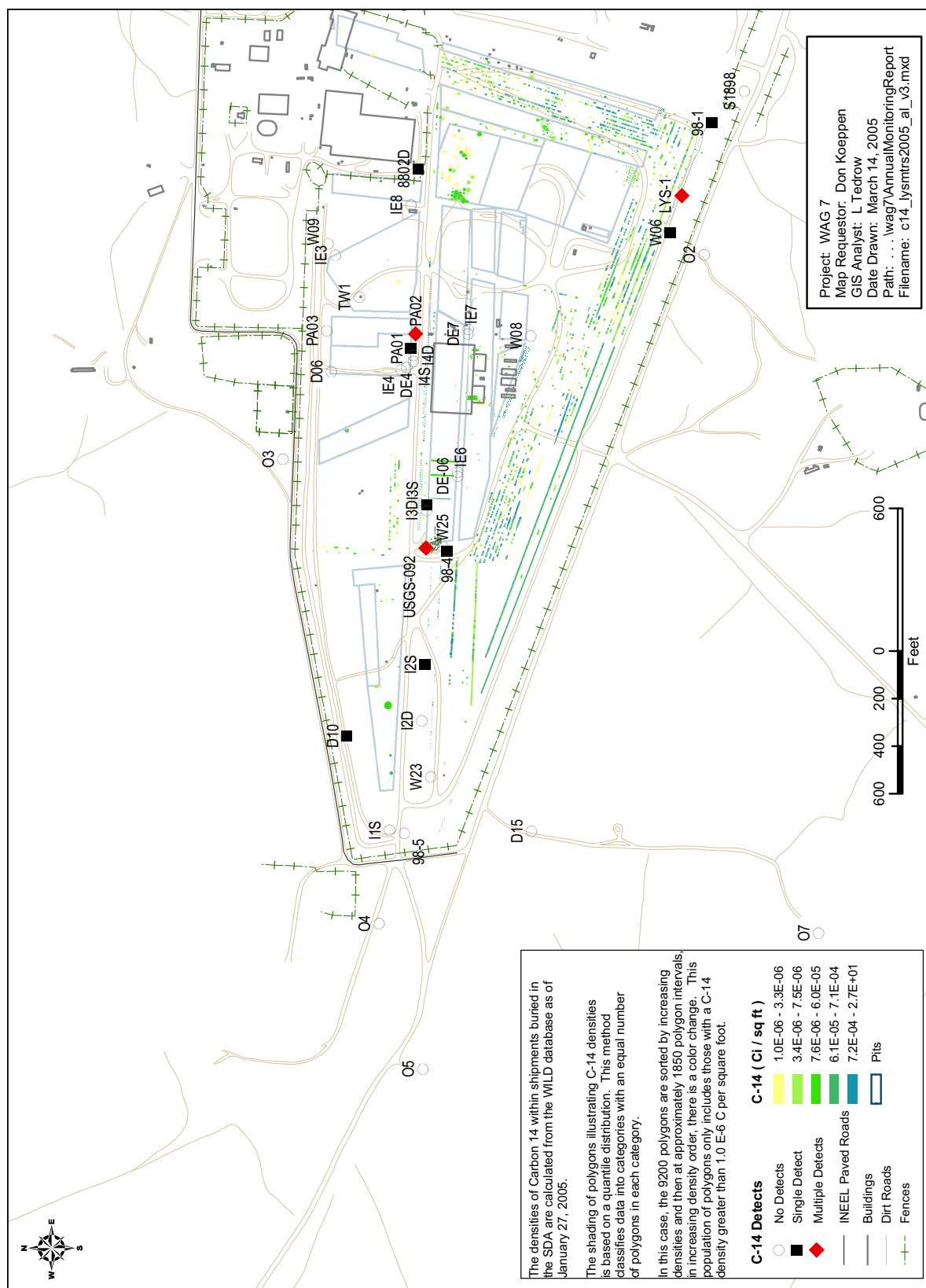


Table 3-13. Summary of maximum concentrations of carbon-14 in aquifer wells at the Radioactive Waste Management Complex from Fiscal Year 1997 through 2004.<sup>a</sup>

Fiscal Year <sup>b</sup>	Maximum Concentration $\pm 1\sigma$ (pCi/L)	Well Location
1997	ND	Various <sup>c</sup>
1998	$6.7 \pm 0.9$	M13S
1999	$10.9 \pm 0.7$	M14S
2000	$5.3 \pm 0.5$	M6S
2001	$42.1 \pm 1.4$	M17S
2002	$7.5 \pm 0.9$	M17S
2003	ND	Various <sup>c</sup>
2004	ND	Various <sup>c</sup>

a. MCL = 2,000 pCi/L

b. Fiscal year spans from October 1 to September 30 (e.g., FY1997 is October 1, 1996, to September 30, 1997).

c. Various locations were sampled.

FY = fiscal year

MCL = maximum contaminant level

ND = not detected

Carbon-14 in soil-gas samples was slightly above background in seven of the 10 sampled wells. No trends were indicated within any wells or across the SDA, but C-14 was not detected at depths greater than 53 m (175 ft). Carbon-14 in samples collected near the beryllium block disposals in SVR 20 were about four orders of magnitude higher than background levels. Carbon-14 in samples near SVR 12 was about two orders of magnitude over background. Carbon-14 concentrations in soil-gas samples near activated steel (SVR 12) are much lower than the concentrations observed near activated beryllium (SVR 20). This difference is expected because of the relatively low concentration of C-14 in stainless steel and the much slower corrosion rate of stainless steel. Correlations between vapor and soil moisture results cannot be made, because C-14 was not detected in soil moisture from any of the nearby lysimeter wells.

Trends are not apparent in any of the RWMC monitoring wells, and the detectable concentrations in liquid samples are well below the MCL of 2,000 pCi/L and the aquifer 1E-05 RBC of 307 pCi/L, except for Lysimeter LYS-1:L41, which exceeded the MCL and RBC. Elevated concentrations of C-14 are expected in Lysimeter LYS-1:L41 because the lysimeter is located near disposed beryllium blocks, and vapor concentrations in this area are high. Significant amounts of C-14 and tritium have leached into the surrounding area from the highly radioactive beryllium blocks. Lysimeter LYS-1:L41 was taken out of service in FY-2004 because it was located in the region impacted by grout when nearby beryllium blocks were grouted with paraffin during July and August 2004. Table 3-13 presents maximum detections of C-14 in the aquifer since FY 1997.

### 3.3 Chlorine-36

Chlorine-36 is a radioisotope generated by nuclear reactor operations and weapons testing. In addition, it is produced in extremely low concentrations in the environment by cosmic ray interactions with argon. It decays by the emission of beta particles, has a 30,100-year half-life, and was identified in the *Second Addendum to the Work Plan for the OU 7-13/14 Waste Area Group 7 Comprehensive Remedial Investigation/Feasibility Study* (Holdren and Broomfield 2004) as a COC, primarily for the groundwater ingestion exposure pathways. Approximately 1.12 Ci of Cl-36 was buried in the SDA, according to inventory estimates through 1999.

### 3.3.1 Waste Zone

Eighteen waste zone lysimeters were sampled every quarter in FY 2004 and Lysimeters 741-08-L1 and 743-18-L2 (located in Pits 10 and 4, respectively) were the only waste zone lysimeters to yield samples. Unfortunately, the volumes obtained were very small, permitting analysis for gamma-emitting radionuclides, but not Cl-36.

### 3.3.2 Vadose Zone

**3.3.2.1 Lysimeter Samples at Depths of 0–35 ft.** Twenty-one Cl-36 analyses were performed on soil-moisture samples collected from nine shallow lysimeters in and around the SDA in FY 2004, resulting in one positive detection (see Table 3-14). The detection is associated with the August 2004 sampling event, and the detected concentration is considerably below the 1E-05 RBC (i.e., 144 pCi/L). There have been no previous detections of Cl-36 from this particular lysimeter (PA01:L15). This well also contains elevated concentrations of possible anthropogenic uranium, and the fission product Tc-99 is occasionally detected in this well. Therefore, the presence of the activation product Cl-36 is probable. The occurrence of Cl-36 detections in shallow lysimeters since 1997 is summarized in Figure 3-14; routine Cl-36 monitoring did not begin until October 2002. Sporadic detections occur, but no apparent trends are exhibited in the shallow lysimeters.

Table 3-14. Chlorine-36 detections in Fiscal Year 2004 Subsurface Disposal Area vadose zone soil-moisture samples from the 0–35-ft depth interval.

Radionuclide	Sample Date	Well: Lysimeter	Lysimeter Depth (ft)	Sample Result $\pm 1\sigma$ (pCi/L)	Minimum detectable Concentration (pCi/L)	Local Soil-Moisture Background <sup>a</sup> (pCi/L)	RBC <sup>b</sup> (pCi/L)
Cl-36	08/30/04	PA01:L15	14.3	<b>16 <math>\pm 3</math><sub>J</sub><sup>c</sup></b>	7	0.0	144

a. The local soil-moisture background concentration for Cl-36 is essentially zero and is defined as a nondetect (i.e., a result less than or equal to its MDA and less than or equal to three times its reported  $1\sigma$  uncertainty). Local soil-moisture background concentrations are established with lysimeter samples regularly collected from the “O” and D15-series lysimeter wells located outside of the SDA.

b. RBC = 1E-05 for drinking water. The RBCs for the aquifer are provided here as a basis of comparison.

c. **Black bold font** indicates sample concentrations less than the RBC, but exceeding local soil-moisture background concentrations (see Footnote a). The concentration value with a “J” subscript denotes that a “J” data validation qualifier flag was assigned. The “J” flag was assigned to the Cl-36 result because of duplicate imprecision. The result is questionable but usable, but should only be used as an estimated quantity.

RBC = risk-based concentration

SDA = Subsurface Disposal Area

**3.3.2.2 Lysimeter Samples at Depths of 35–140 ft.** Thirty-one Cl-36 analyses were performed on soil-moisture samples collected from 13 intermediate-depth lysimeters in and around the SDA in FY 2004, with two detections. The two detections are associated with the May 2004 sampling event, and the detected concentrations are considerably below the 1E-05 RBC (i.e., 144 pCi/L) (see Table 3-15). This is the first time Cl-36 was detected in Well D06 since April 2003, and the second time in Well I-1S since October 2002. Sporadic detections of Cl-36 at these monitoring locations in the vadose zone are not surprising, because elevated concentrations of uranium are consistently detected in these two lysimeter wells, and Tc-99 is frequently detected in Well D06. The occurrence of Cl-36 detections in intermediate-depth lysimeters since 1997 is summarized in Figure 3-15; routine Cl-36 monitoring did not begin until October 2002. Sporadic detections occur, but no apparent trends are exhibited in the intermediate depth.

Table 3-15. Chlorine-36 detections in Fiscal Year 2004 Subsurface Disposal Area vadose zone soil-moisture samples from the 35–140-ft depth interval.

Radionuclide	Sample Date	Well: Lysimeter	Lysimeter Depth (ft)	Sample Result $\pm 1\sigma$ (pCi/L)	MDC (pCi/L)	Local Soil-Moisture Background <sup>a</sup> (pCi/L)	RBC <sup>b</sup> (pCi/L)
Cl-36	05/03/04	D06:DL02	88	<b>28 <math>\pm</math> 8<sup>c</sup></b>	26.6	0.0	144
Cl-36	05/04/04	I-1S:DL09	101	<b>32 <math>\pm</math> 9<sup>c</sup></b>	31.5	0.0	144

a. The local soil moisture background concentration for Cl-36 is essentially zero and defined as a nondetect (i.e., a result less than or equal to its MDA and less than or equal to three times its reported  $1\sigma$  uncertainty). Local soil-moisture background concentrations are established with lysimeter samples regularly collected from the “O” and D15-series lysimeter wells located outside of the SDA.

b. RBC =  $1\text{E-}05$  for drinking water. The RBCs for the aquifer are provided here as a basis of comparison.

c. **Black bold font** indicates sample concentrations less than the RBC, but exceeding local soil-moisture background concentrations (see Footnote a).

MDA = minimum detectable activity

MDC = minimum detectable concentration

RBC = risk-based concentration

SDA = Subsurface Disposal Area

Chlorine-36 Radioactive Waste Management Complex Lysimeters (0–35 ft)																	
FY	Qtr	98-1: L35	98-4: L38	98-5: L39	D15: DL07	PA01: L15	PA02: L16	PA03: L33	W05: L25	W06: L27	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
1997	1–4																
1998	1–4																
1999	1–4																
2000	1–4																
2001	1–4																
2002	1–4																
2003	1			3.5							5.8			32*			
	2																
	3																
	4																
2004	1																
	2																
	3																
	4					16*											
Key		Analysis was performed, but Cl-36 was not detected.															
		Cl-36 was detected (pCi/L.)															
If more than one positive detection occurred in a single quarter, then only the highest concentration is listed. * Indicates a positive detection that received a “J” qualifier flag because of a minor quality control anomaly. Note: 1E-05 RBC = 144 pCi/L FY = fiscal year      RBC = risk-based concentration      RWMC = Radioactive Waste Management Complex																	

Figure 3-14. Occurrences of chlorine-36 detections in shallow lysimeters.

Chlorine-36 Radioactive Waste Management Complex Lysimeters (35–140 ft)															
FY	Qtr	D06: DL01	D06: DL02	D15: DL06	I-1S: DL09	I-2S: DL11	I-3S: DL13	I-4S: DL15	I-5S: DL16	O2: DL20	O3: DL22	O4: DL24	O5: DL25	O7: DL28	TW1: DL04
1997	1–4														
1998	1–4														
1999	1–4														
2000	1–4														
2001	1–4														
2002	1–4														
2003	1				5.6										3.7
	2														
	3														
	4														
2004	1														
	2														
	3		28		32										
	4														
Key		Analysis was performed for Cl-36, but none was detected.													
		Cl-36 was detected (pCi/L).													
		If more than one positive detection occurred in a well in a single quarter, then only the highest concentration is listed.													
		Note: 1E-05 RBC = 144 pCi/L FY = fiscal year RBC = risk-based concentration													

Figure 3-15. Occurrences of chlorine-36 detections in intermediate-depth (35–140 ft) lysimeters.

**3.3.2.3 Lysimeter and Perched Water Samples at Depths Greater than 140 ft.** Thirty-two Cl-36 analyses were performed on samples collected from 14 lysimeters and three perched water wells in and around the SDA in FY 2004, with no positive detections. The occurrence of Cl-36 detections since 1997 is summarized in Figure 3-16; routine Cl-36 monitoring did not begin until October 2002. Lysimeter wells with an “IE” and “DE” prefix were installed in the deep vadose zone in FY 2003, and some have yielded sufficient sample volumes for Cl-36 analysis. Apparent trends are exhibited in the deeper depths.

### 3.3.3 Aquifer

Forty-nine Cl-36 analyses were performed on aquifer samples collected from 15 monitoring wells in the vicinity of the RWMC in FY 2004, with no detections. Chlorine-36 occurrences in aquifer samples, since 1997, are summarized in Figure 3-17. At the end of 2004, the frequency at which the RWMC aquifer was monitored changed to biannually; thus only data from the first three quarters of FY 2004 are available and are shown in Figure 3-18. No RWMC aquifer samples were analyzed for Cl-36 in FY 2003. Chlorine-36 was identified as a contaminant of potential concern (COPC) in the *Interim Risk Assessment and Contaminant Screening for the Waste Area Group 7 Remedial Investigation* (Becker et al. 1998), but was not routinely analyzed for until 2001; thus, no sample data exist from before that time. The analytical priority and sampling and analysis schedule for Cl-36 was officially established in 2003.

Chlorine-36																							
Radioactive Waste Management Complex Perched Water and Lysimeters (>140 ft)																							
FY	Qtr	8802D	DE4: DL33	DE7: DL36	DE7: DL37	D10	I2D: DL10	I3D: DL12	I4D: DL14	IE3: DL30	IE4: DL32	IE6: DL34	IE7: DL35	IE8: DL38	O2: DL19	O3: DL21	O4: DL23	O6: DL26	O7: DL27	O8: DL29	S1898: DL40	TW1: DL03	USGS- 092
1997	1-4																						
1998	1-4																						
1999	1-4																						
2000	1-4																						
2001	1-4																						
2002	1-4																						
2003	1																						8.7
	2																						
	3																						
	4																						
2004	1																						
	2																						
	3																						
	4																						
Key			Analysis was performed for Cl-36, but none was detected.																				
			Cl-36 was detected (pCi/L).																				
			If more than one positive detection occurred in a well in a single quarter, only the highest concentration is listed. Note: 1E-05 RBC = 144 pCi/L																				
			FY = fiscal year RBC = risk-based concentration																				

Figure 3-16. Occurrences of chlorine-36 detections in deep-depth (&gt;140 ft) lysimeters.



Chlorine-36 Radioactive Waste Management Complex Aquifer-Monitoring Wells																	
FY	Qtr	AllA31	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	M1S	M3S	M4D	M6S	M7S	OW-2	USGS-127
1997	1–4																
1998	1–4																
1999	1–4																
2000	1–4																
2001	1																
	2		OOS														
	3		OOS														
	4		OOS														
2002	1																
	2		OOS														
	3		OOS														
	4		OOS														
2003	1		OOS														
	2		OOS														
	3		OOS														
	4		OOS														
2004	1		OOS														
	2		OOS														
	3		OOS														
Key		Analysis was performed, but Cl-36 was not detected.															
		Cl-36 was detected (pCi/L).															
	If more than one positive detection occurred in a single quarter, then only the highest concentration is listed. Note: MCL = 700 pCi/L. 1E-05 RBC = 144 pCi/L.																
	FY = fiscal year MCL = maximum contaminant level OOS = out of service. Well rendered inoperable after attempts at repairs were unsuccessful RBC = risk-based concentration																

Figure 3-17. Occurrences of chlorine-36 detections in the aquifer-monitoring wells since Fiscal Year 1997.

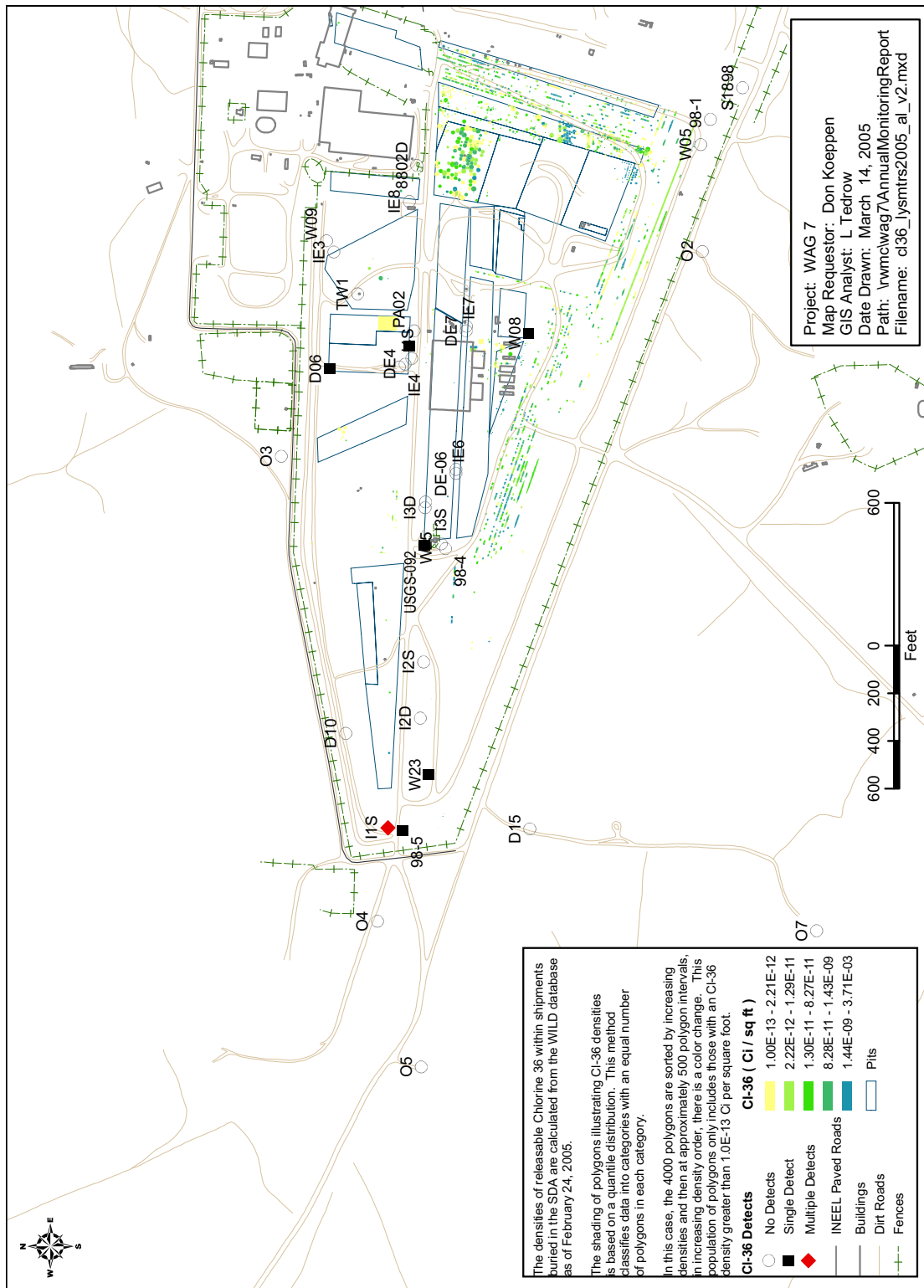


Figure 3-18. Chlorine-36 disposal locations and vadose zone detection locations at the Subsurface Disposal Area since 2002.

### 3.3.4 Summary of Chlorine-36

Analytical data to evaluate the nature and extent of Cl-36 contamination at the RWMC are somewhat limited, because Cl-36 was not routinely analyzed for until 2001, even though it was identified as a COPC in 1998. Also, the analytical priority and sampling and analysis schedule for Cl-36 was not officially established until the end of FY 2003; therefore, minimal data existed before that time. In FY 2004, 94 vadose zone sample analyses were performed, and three positive detections were observed. Locations where Cl-36 was detected in the vadose zone are the same lysimeter wells where other contaminants have been detected in the past. Other detected contaminants are primarily uranium isotopes and Tc-99. Historically, detections are rare and have been confined to the vadose zone between 0 and 31 m (0 and 101 ft). All positive results were below the MCL of 700 pCi/L and the 1E-05 aquifer RBC of 144 pCi/L.

Maximum concentrations of Cl-36 in vadose zone soil moisture and perched water since October 2002 are shown in Table 3-16; Table 3-17 shows the aquifer maximums. Locations of detected Cl-36 in vadose zone samples are depicted in Figure 3-17 along with the known Cl-36 disposals.

## 3.4 Tritium

Tritium is not a COPC. However, it is monitored because its distribution and migration are important to the overall understanding of contaminant movement in the vadose zone and aquifer, because there are uncertainties about whether the source of tritium is from the SDA or upgradient facilities. Tritium is produced naturally by interactions of cosmic rays and atmospheric gases, and tritium is also produced by nuclear reactor operations.

Approximately 2.67E+06 Ci of tritium was buried in the SDA, according to inventory estimates through 1999. Since 2001, tritium in the vapor and soil moisture has been evaluated in detail at SVRs 12 and 20. In FY 2004, a study of tritium in vapor was conducted through out the SDA using samples from OCVZ monitoring ports. To simplify data presentation, tritium results from liquid and core samples are presented first, followed by the vapor and soil moisture results in the SVR study, then the SDA-wide vapor monitoring results. The summary discusses all the data together.

### 3.4.1 Results from Analyses of Liquid and Solid Samples

This section presents the results from liquid and solid samples collected from SDA monitoring in the waste zone, vadose zone, and the aquifer.

### 3.4.2 Waste Zone

No results are available for tritium in the waste zone. Vapor monitoring results from SVRs 12 and 20 are discussed in Section 3.4.2.

**3.4.2.1 Vadose Zone.** Tritium was detected at low concentrations in numerous vadose zone soil-moisture and perched water samples in FY 2004. Measured concentrations typically range from approximately 200–1,800 pCi/L, with one sample exceeding 10,000 pCi/L. Because tritium was not a WAG 7 COPC, the analysis priority for tritium in soil moisture was at the end of the analytical priority list; thus, many data gaps exist. Although tritium is not a risk driver, it is a mobile contaminant and co-occurs with activation products that are of concern (e.g., C-14 and Tc-99); thus, tritium was moved up on the analytical priority list (see Table 2-1) to facilitate trend detection and early warning. Reprioritization in FY 2004 led to collection of tritium data from multiple wells; this helped fill some of the data gaps and determine the extent of tritium contamination in the SDA. Results for tritium are presented in the following sections for soil and moisture samples.

Table 3-16. Summary of maximum concentrations of chlorine-36 in vadose zone soil-moisture and perched water samples at the Radioactive Waste Management Complex from Fiscal Years 1997 through 2004.<sup>a</sup>

Sampling Range (ft bls)	Fiscal Year <sup>b</sup>	Maximum Concentration $\pm 1\sigma$ (pCi/L) <sup>c</sup>	Sample Location
Lysimeters 0–35 ft	1997	NA	—
	1998	NA	—
	1999	NA	—
	2000	NA	—
	2001	NA	—
	2002	NA	—
	2003	$32.3 \pm 1.6$	W23:L07
	2004	$16 \pm 3$	PA01:L15
Lysimeters 35–140 ft	1997	NA	—
	1998	NA	—
	1999	NA	—
	2000	NA	—
	2001	NA	—
	2002	NA	—
	2003	$5.6 \pm 0.9$	I1S:DL09
	2004	$32 \pm 9$	I1S:DL09
Lysimeters >140 ft	1997	NA	—
	1998	NA	—
	1999	NA	—
	2000	NA	—
	2001	NA	—
	2002	NA	—
	2003	ND	Various <sup>d</sup>
	2004	ND	Various <sup>d</sup>
Perched water wells >140 ft	1997	NA	—
	1998	NA	—
	1999	NA	—
	2000	NA	—
	2001	NA	—
	2002	NA	—
	2003	$8.7 \pm 1.0$	USGS-92
	2004	ND	Various <sup>d</sup>

a. MCL = 700 pCi/L

b. Fiscal year spans from October 1 to September 30 (e.g., Fiscal Year 1997 is October 1, 1996, to September 30, 1997).

c. NA = not analyzed ND = not detected

d. Various locations were sampled.

MCL = maximum contaminant level

Table 3-17. Summary of maximum concentrations of chlorine-36 in aquifer wells at the Radioactive Waste Management Complex from Fiscal Years 1997 through 2004.<sup>a</sup>

Fiscal Year <sup>b</sup>	Maximum Concentration $\pm 1\sigma$ (pCi/L) <sup>c</sup>	Well Location
1997	NA	—
1998	NA	—
1999	NA	—
2000	NA	—
2001	ND	Various <sup>d</sup>
2002	ND	Various <sup>d</sup>
2003	NA	—
2004	ND	Various <sup>d</sup>

a. MCL = 700 pCi/L

b. Fiscal year spans from October 1 to September 30 (e.g., FY 1997 is October 1, 1996, through September 30, 1997).

c. NA = not analyzed ND = not detected

d. Various locations were sampled.

MCL = maximum contaminant level

### 3.4.2.2 Subsurface Soil Samples Collected While Drilling Lysimeter Well RWMC-2005.

In April 2004, while drilling Lysimeter Well RWMC-2005 in the east end of the SDA (see Figure 2-3), radioactivity above background was detected in the drilling soil returns. Drilling was stopped, and three soil samples were collected from these returns. The samples were analyzed for tritium, and tritium was detected at a low concentration in one of the samples (see Table 3-18).

Table 3-18. Tritium detection in Fiscal Year 2004 Subsurface Disposal Area vadose zone soil sample.

Radionuclide	Sample Date	Well: Lysimeter	Lysimeter Depth (ft)	Sample Result $\pm 1\sigma$ (pCi/g)	MDC (pCi/g)	INL Soil Background UTL <sup>a</sup> (pCi/g)	Soil RBC <sup>b</sup> (pCi/g)
Tritium	04/26/04	RWMC-2005	8.9	<b>13.8 <math>\pm</math> 3.7<sup>c</sup></b>	12.1	NE	NE

a. INL surficial soil background 95% upper tolerance concentration limits for grab samples are not directly applicable to subsurface soils, but are provided here only as a basis for comparison. The surficial soil background tolerance limits were established in 1996 (Rood, Harris, and White 1996).

b. Calculated RBC for soil is equivalent to an increased cancer of 1E-05.

c. **Black bold font** indicates sample concentrations less than the RBC, but exceeding surficial soil background upper tolerance limit (see Footnote a).

INL = Idaho National Laboratory

MDC = minimum detectable concentration

NE = not established

RBC = risk-based concentration

SDA = Subsurface Disposal Area

UTL = upper 95% tolerance level with 95% confidence

**3.4.2.3 Lysimeter Samples at Depths of 0–35 ft.** Twenty tritium analyses were performed on soil-moisture samples collected from nine shallow lysimeters in and around the SDA in FY 2004, with 10 positive detections (see Table 3-19). The detected concentrations varied from 241 pCi/L to over 10,000 pCi/L. Samples from Wells PA01 and W25 have anomalously high tritium concentrations of 10,200 and 3,680 pCi/L, respectively. These relatively high concentrations are unexpected because these wells have no previous history of recurrent tritium detections. Subsequent samples collected from Well PA01 have not shown positive detections, and recent samples from Well W25 show much lower

concentrations (see Table 3-19). Results for tritium in the shallow vadose zone samples, since routine monitoring began in 1997, are summarized in Figure 3-19. Over the past seven years numerous detections have occurred in the shallow vadose zone, but no apparent trends have been exhibited thus far. Historically, shallow Lysimeter Wells PA02, W08, W23 and W25 exhibit the most frequent detections, although no spatial relationship is apparent in the shallow region of the vadose zone (see Figure 3-19). At such low concentrations, continued sampling is necessary to establish the presence or absence of tritium in some of these monitoring wells.

Table 3-19. Tritium detections in Fiscal Year 2004 Subsurface Disposal Area vadose zone soil-moisture samples from the 0–35-ft depth interval.

Radionuclide	Sample Date	Well: Lysimeter	Lysimeter Depth (ft)	Sample Result $\pm 1\sigma$ (pCi/L)	MDC (pCi/L)	Local Soil Moisture Background <sup>a</sup> (pCi/L)	RBC <sup>b</sup> (pCi/L)
Tritium	10/28/03	PA01:L15	14.3	<b>10,200 <math>\pm</math> 802<sup>c</sup></b>	152	0.0	9,392
	10/27/03	W08:L13	11.3	<b>539 <math>\pm</math> 71<sup>d</sup></b>	208	0.0	9,392
	10/27/03	W25:L28	15.5	<b>3,680 <math>\pm</math> 618<sup>d</sup></b>	1,850	0.0	9,392
	05/05/04	W25:L28	15.5	<b>390 <math>\pm</math> 56<sub>J</sub><sup>d</sup></b>	158	0.0	9,392
	05/05/04	98-4:L38	17.0	<b>1,500 <math>\pm</math> 80<sup>d</sup></b>	162	0.0	9,392
	05/05/04	W23:L07	18.8	<b>431 <math>\pm</math> 55<sub>J</sub><sup>d</sup></b>	150	0.0	9,392
	08/23/04	W09:L23	14.8	<b>375 <math>\pm</math> 83<sup>d</sup></b>	230	0.0	9,392
	08/23/04	W23:L07	18.8	<b>330 <math>\pm</math> 87<sup>d</sup></b>	275	0.0	9,392
	08/23/04	W23:L09	7.7	<b>306 <math>\pm</math> 81<sup>d,e</sup></b>	255	0.0	9,392
	08/25/04	W25:L28	15.5	<b>241 <math>\pm</math> 76<sup>d,e</sup></b>	213	0.0	9,392

a. The local soil moisture background concentration for tritium is essentially zero and defined as a nondetect (i.e., a result less than or equal to its MDA and less than or equal to three times its reported  $1\sigma$  uncertainty). Local soil-moisture background concentrations are established with lysimeter samples regularly collected from the “O” and D15-series lysimeter wells located outside of the SDA.

b. RBC =  $1\text{E-}05$  for drinking water. The RBCs for the aquifer are provided here as a basis of comparison.

c. **Red bold font** indicates sample concentrations exceeding the RBC.

d. **Black bold font** indicates sample concentrations less than the RBC, but exceeding local soil-moisture background concentrations (see Footnote a). Concentration values with a “J” subscript denote that “J” data validation qualifier flags were assigned. The “J” flags were assigned to the tritium results because of blank contamination. The results are questionable but usable, but should only be used as estimated quantities.

e. Tritium analysis results in the 200 to 300 pCi/L range reported as positive detections should be treated with prudence, as this concentration range is near the limits of detection for soil-moisture samples using standard analysis methodology.

MDA = minimum detectable activity

MDC = minimum detectable concentration

RBC = risk-based concentration

SDA = Subsurface Disposal Area

**3.4.2.4 Lysimeter Samples at Depths of 35–140 ft.** Thirty-five tritium analyses were performed on soil-moisture samples collected from 13 intermediate-depth lysimeters in and around the SDA in FY 2004, with 10 positive detections (see Table 3-20). The detected concentrations range from 174–1,770 pCi/L. Well TW1 has more than a 6-year history of tritium detections, while detections in Wells I2S and I3S are recent occurrences within the past year. It is conjectured that tritium existed at Wells I2S and I3S for some time; however, tritium monitoring did not begin on these two lysimeter wells until analytical priorities were revised in 2003. Results for the intermediate vadose zone samples, since routine monitoring began in 1997, are summarized in Figure 3-20. The average tritium concentration in Well TW1 over the past 6 years is approximately 2,000 pCi/L; however, the concentration is gradually decreasing at a rate corresponding to its radioactive decay half-life (see Figure 3-21).

Tritium Radioactive Waste Management Complex Lysimeters (0–35 ft)																	
FY	Qtr	98-1: L35	98-4: L38	98-5: L39	D15: DL07	PA01: L15	PA02: L16	PA03: L33	W05: L25	W06: L27	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
1997	1																
	2																
	3						243			2,510		129				154	366
	4						167			3,270	1,140						235
1998	1																
	2																
	3						328										
	4					991				7,290					383		
1999	1						1,380			8,650							
	2																
	3																
	4																
2000	1									9,100							
	2																
	3									9,070	815						
	4																
2001	1																
	2																
	3																
	4																
2002	1																
	2																
	3																
	4																
2003	1													187			
	2																
	3																
	4						368										
2004	1					10,200					539						3,680
	2																
	3		1,500											431*			390*
	4												375	330		306	241
Key		Analysis was performed, but tritium was not detected.															
		Tritium was detected (pCi/L).															
	If more than one positive detection occurred in a single quarter, then only the highest concentration is listed.																
	* Indicates a positive detection that received a “J” qualifier flag because of a minor quality control anomaly.																
Note: 1E-05 RBC = 9,392 pCi/L																	
FY = fiscal year																	
RBC = risk-based concentration																	

Figure 3-19. Occurrences of tritium detections in the shallow lysimeters since Fiscal Year 1997.

Table 3-20. Tritium detections in Fiscal Year 2004 Subsurface Disposal Area vadose zone soil-moisture samples from the 35–140-ft depth interval.

Radionuclide	Sample Date	Well: Lysimeter	Lysimeter Depth (ft)	Sample Result $\pm 1\sigma$ (pCi/L)	MDC (pCi/L)	Local Soil Moisture Background <sup>a</sup> (pCi/L)	RBC <sup>b</sup> (pCi/L)
Tritium	10/27/03	I-2S:DL11	92	<b>596 <math>\pm</math> 67<sup>c</sup></b>	186	0.0	9,392
	10/28/03	I-3S:DL13	93	<b>795 <math>\pm</math> 74<sub>J</sub><sup>c</sup></b>	200	0.0	9,392
	10/27/03	TW1:DL04	101.7	<b>1720 <math>\pm</math> 89<sup>c</sup></b>	203	0.0	9,392
	02/02/04	I-2S:DL11	92	<b>526 <math>\pm</math> 63<sup>c</sup></b>	174	0.0	9,392
	05/04/04	I-2S:DL11	92	<b>485 <math>\pm</math> 60<sup>c</sup></b>	163	0.0	9,392
	05/04/04	I-3S:DL13	93	<b>696 <math>\pm</math> 68<sup>c</sup></b>	174	0.0	9,392
	05/04/04	O-2S:DL20	106	<b>174 <math>\pm</math> 52<sup>c,d</sup></b>	164	0.0	9,392
	05/03/04	TW1:DL04	101.7	<b>1770 <math>\pm</math> 89<sup>c</sup></b>	185	0.0	9,392
	08/25/04	I-2S:DL11	92	<b>584 <math>\pm</math> 89<sup>c</sup></b>	265	0.0	9,392
	08/30/04	I-3S:DL13	93	<b>843 <math>\pm</math> 95<sup>c</sup></b>	271	0.0	9,392

a. The local soil-moisture background concentration for tritium is essentially zero and defined as a nondetect (i.e., a result less than or equal to its MDA and less than or equal to three times its reported  $1\sigma$  uncertainty). Local soil-moisture background concentrations are established with lysimeter samples regularly collected from the “O” and D15-series lysimeter wells located outside of the SDA.

b. RBC =  $1\text{E-}05$  for drinking water. The RBCs for the aquifer are provided here as a basis of comparison.

c. **Black bold font** indicates sample concentrations less than the RBC, but exceeding local soil-moisture background concentrations (see Footnote a). The concentration value with a “J” subscript denotes that a “J” data validation qualifier flag was assigned. The “J” flag was assigned to the October 2003 tritium result because the laboratory failed to prepare an MS or MSD with the sample batch. Both the MS and MSD provide an analytical quality check to assess matrix interference. The results are usable, but should only be used as estimated quantities.

d. Tritium analysis results in the 200–300 pCi/L range reported as positive detections should be treated with prudence, as this concentration range is near the limits of detection for soil-moisture samples using standard analysis methodology.

MDA = minimum detectable activity  
MDC = minimum detectable concentration  
MS =matrix spike  
MSD = matrix spike duplicate  
RBC = risk-based concentration  
SDA = Subsurface Disposal Area



Tritium Radioactive Waste Management Complex Lysimeters (35–140 ft)															
FY	Qtr	D06: DL01	D06: DL02	D15: DL06	I-1S: DL09	I-2S: DL11	I-3S: DL13	I-4S: DL15	I-5S: DL16	O2: DL20	O3: DL22	O4: DL24	O5: DL25	O7: DL28	TW1: DL04
1997	1														
	2														
	3														
	4														
1998	1														
	2														
	3														2,520
	4														1,680
1999	1														2,950
	2														
	3														
	4														
2000	1														
	2														
	3														
	4														
2001	1														
	2														
	3														
	4														
2002	1														
	2														
	3														
	4														
2003	1														
	2														
	3														
	4				277	580					228				1,690
2004	1					596	795*								1,720
	2					526									
	3					485	696			174					1,770
	4					584	843								
Key		Analysis was performed, but tritium was not detected.													
		Tritium was detected (pCi/L).													
	If more than one positive detection occurred in a single quarter, then only the highest concentration is listed.														
	* Indicates a positive detection that received a “J” qualifier flag because of a minor quality control anomaly.														
Note: 1E-05 RBC = 9,392 pCi/L															
FY = fiscal year															
RBC = risk-based concentration															

Figure 3-20. Occurrences of tritium detections in intermediate-depth (35–140 ft) lysimeters since Fiscal Year 1997.

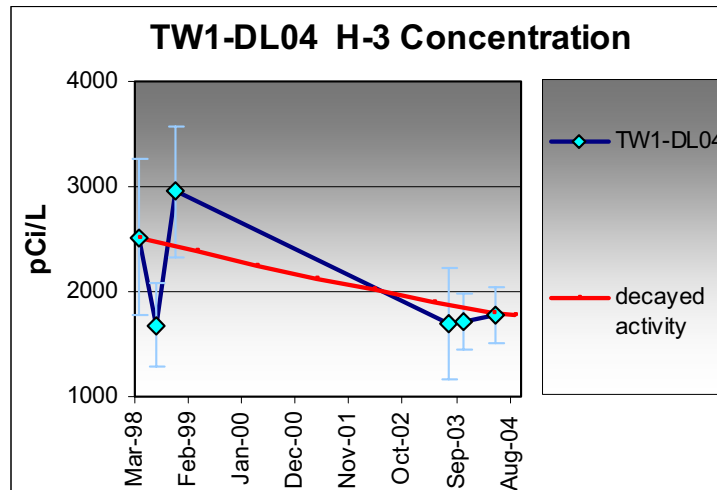


Figure 3-21. Tritium concentration history for Lysimeter TW1:DL04.

**3.4.2.5 Lysimeter Samples at Depths Greater than 140 ft.** Thirty-eight tritium analyses were performed on deep-suction lysimeter samples collected from 14 lysimeters and three perched water wells in and around the SDA in FY 2004, with 13 positive detections (see Table 3-21). The detected concentrations range from 204–1,680 pCi/L. Results for the samples, since routine monitoring began in 1997, are summarized in Figure 3-22. The “I” and “O” series wells were installed between November 1999 and March 2000, and the first samples were collected in June 2000. Tritium concentrations at most lysimeter locations appear to be staying constant or decreasing somewhat, except for Perched Water Well USGS-092. Tritium detections are occurring more frequently in this perched water well, and a possible concentration trend may be developing (see Figure 3-22). This potential trend, however, is obscured in the analytical noise (as illustrated in Figure 3-22 with  $3\sigma$  error bars), and will require further monitoring to determine further trends.

Table 3-21. Tritium detections in Fiscal Year 2004 Subsurface Disposal Area vadose zone soil-moisture and perched water samples from depths greater than 140 ft.

Radionuclide	Sample Date	Well: Lysimeter	Lysimeter Depth (ft)	Sample Result $\pm 1\sigma$ (pCi/L)	MDC (pCi/L)	Local Soil Moisture Background <sup>a</sup> (pCi/L)	RBC <sup>b</sup> (pCi/L)
Tritium	10/29/03	8802D	220	<b>519 <math>\pm</math> 66<sup>c</sup></b>	188	0–40 <sup>d</sup>	9,392
	10/27/03	I-2D:DL10	196	<b>1,100 <math>\pm</math> 84<sup>c</sup></b>	218	0.0	9,392
	10/27/03	IE6:DL34	215	<b>1,210 <math>\pm</math> 80<sup>c</sup></b>	199	0.0	9,392
	10/27/03	IE8:DL38	224	<b>1,180 <math>\pm</math> 195<sup>c</sup></b>	585	0.0	9,392
	10/29/04	USGS-092	214	<b>542 <math>\pm</math> 69<sup>c</sup></b>	196	0–40 <sup>d</sup>	9,392
	01/29/04	I-2D:DL10	196	<b>1,110 <math>\pm</math> 163<sup>c</sup></b>	288	0.0	9,392
	01/26/04	TW1:DL03	226.9	<b>1,680 <math>\pm</math> 101<sup>c</sup></b>	216	0.0	9,392
	02/02/04	USGS-092	214	<b>377 <math>\pm</math> 63<sup>c</sup></b>	183	0–40 <sup>d</sup>	9,392
	05/06/04	D10	205.4	<b>628 <math>\pm</math> 63<sup>c</sup></b>	161	0–40 <sup>d</sup>	9,392
	05/05/04	IE6:DL34	215	<b>204 <math>\pm</math> 51<sup>ce</sup></b>	158	0.0	9,392

Table 3-21. (continued).

Radionuclide	Sample Date	Well: Lysimeter	Lysimeter Depth (ft)	Sample Result $\pm 1\sigma$ (pCi/L)	MDC (pCi/L)	Local Soil Moisture Background <sup>a</sup> (pCi/L)	RBC <sup>b</sup> (pCi/L)
	05/06/04	USGS-092	214	<b>431 <math>\pm</math> 58<sup>c</sup></b>	162	0–40 <sup>d</sup>	9,392
	08/25/04	I-2D:DL10	196	<b>1,150 <math>\pm</math> 98<sup>c</sup></b>	267	0.0	9,392
	08/26/04	USGS-092	214	<b>369 <math>\pm</math> 84<sup>c</sup></b>	263	0–40 <sup>d</sup>	9,392

a. The local soil moisture background concentration for tritium is essentially zero and defined as a nondetect (i.e., a result less than or equal to its MDA and less than or equal to three times its reported  $1\sigma$  uncertainty). Local soil-moisture background concentrations are established with lysimeter samples regularly collected from the “O” and D15-series lysimeter wells located outside of the SDA.

b. RBC =  $1\text{E-}05$  for drinking water. The RBCs for the aquifer are provided here as a basis of comparison.

c. **Black bold font** indicates sample concentrations less than the RBC, but exceeding local soil-moisture background concentrations (see Footnote a). Concentration values with a “J” subscript denote that “J” data validation qualifier flags were assigned. The “J” flags were assigned to the October 2003 results because the laboratory failed to prepare a matrix spike MS or MSD with the sample batch. Both the MS and MSD provide an analytical quality check to assess matrix interference. The “J” flags were assigned to the May 2003 results because of blank contamination. The results are usable, but should only be used as estimated quantities.

d. For perched water, aquifer background concentrations are applied instead of soil moisture background.

e. Tritium analysis results in the 200–300-pCi/L range, reported as positive detections, should be treated with prudence because this concentration range is near the limits of detection for soil-moisture samples using standard analysis methodology.

MDA = minimum detectable activity

MS = matrix spike

RBC = risk-based concentration

MDC = minimum detectable concentration

MSD = matrix spike duplicate

SDA = Subsurface Disposal Area

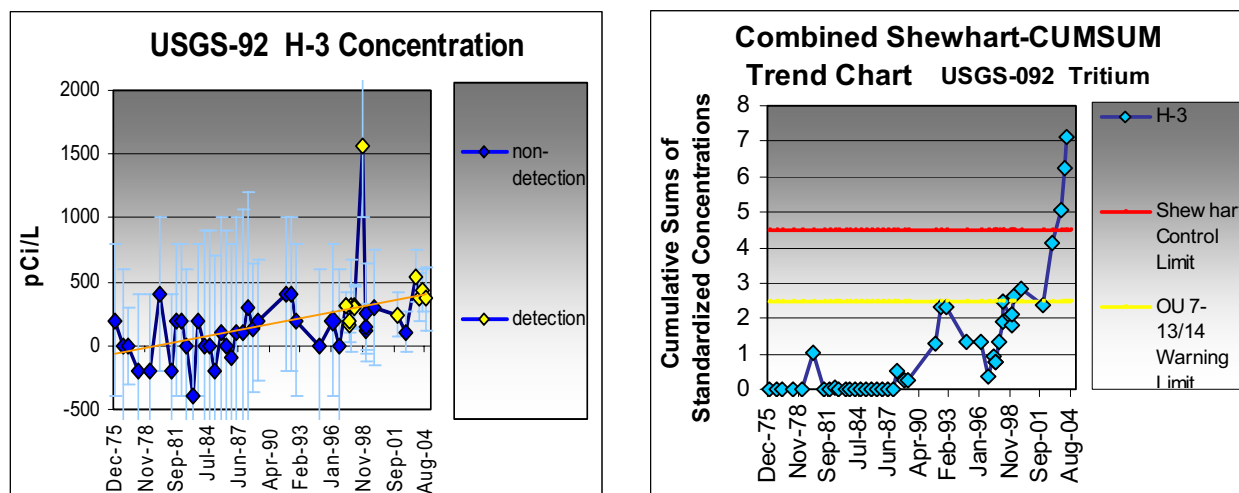


Figure 3-22. Tritium concentration history in Subsurface Disposal Area Perched Water Well USGS-092 since 1976.

### 3.4.3 Aquifer

Thirty-two tritium analyses were performed on aquifer samples collected from 15 monitoring wells in the vicinity of the RWMC in FY 2004, with 12 positive detections above aquifer background levels but significantly below the drinking water MCL (see Table 3-22). Detections of tritium in aquifer samples occur regularly in Wells M3S, M7S, M12S, M14S, M16S, and M17S (see Figure 3-23) and have never occurred in Wells M1S, M4D, M6S, M10S, M11, M13S, M15S, or USGS-127. The occurrence of tritium detections since 1997 is summarized in Figure 3-24. At the end of 2004, the frequency at which the RWMC aquifer was monitored changed to biannually; thus, only data from the first three quarters of

Tritium																							
Radioactive Waste Management Complex Perched Water and Lysimeters (>140 ft)																							
FY	Qtr	8802D	DE4: DL33	DE7: DL36	DE7: DL37	D10	I2D: DL10	I3D: DL12	I4D: DL14	IE3: DL30	IE4: DL32	IE6: DL34	IE7: DL35	IE8: DL38	O2: DL19	O3: DL21	O4: DL23	O6: DL26	O7: DL27	O8: DL29	S1898: DL40	TW1: DL03	USGS- 092
1997	1																						
	2																						
	3																						310
	4																						196
1998	1																						
	2																						314
	3																						
	4																						
1999	1																						1,570
	2																						
	3																						
	4																						
2000	1																						
	2																						
	3																						
	4																						
2001	1																						
	2																						
	3																						
	4																						
2002	1																						
	2																						
	3																						
	4																						
2003	1																						
	2																						
	3																						
	4																						
2004	1	519*					1,100					1,210		1,180									542*
	2						1,110															1,680	377
	3					628*						204											431*
	4						1,150																369
Key		Analysis was performed for tritium, but none was detected.																					
		Tritium was detected (pCi/L).																					
		If more than one positive detection occurred in a well in a single quarter, only the highest concentration is listed.																					
		* Indicates a positive detection that received a "J" qualifier flag because of a minor quality control anomaly.																					
		Note: 1E-05 RBC = 9,392 pCi/L																					
		RBC = risk-based concentration																					

Figure 3-23. Occurrences of tritium detections in the deep-depth (&gt;140 ft) lysimeters since Fiscal Year 1997.

Tritium Radioactive Waste Management Complex Aquifer-Monitoring Wells																		
FY	Qtr	A11- A31	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	M1S	M3S	M4D	M6S	M7S	OW2	RWMC Prod	USGS -127
1997	1																	
	2																1,490	
	3											1,910			1,430		1,320	
	4																	
1998	1											1,540			1,250		1,230	
	2																1,130	
	3											1,770			1,370			
	4				1,990		1,670					1,920			1,440		1,550	
1999	1				1,610		1,860					1,410			1,260		1,600	
	2				1,360		1,870					1,710			1,400		1,500	
	3				1,570		1,710					1,600			1,400		1,600	
	4				1,390		1,740					1,700			1,420		1,500	
2000	1				1,660		1,520					1,470			1,150		1,600	
	2				1,500		1,860		1,020			1,690			1,440		1,290	
	3									836							1,140	
	4				1,370		1,640		1,480	1,010		1,760			1,250		1,500	
2001	1						1,730		1,040	613		1,360			1,150		1,040	
	2		OOS		776		889					915			802		1,200	
	3		OOS		1,480		1,470		809	533		1,270			1,110		1,500	
	4		OOS		1,640		1,520		1,170	837		1,680			1,240		1,200	
2002	1		OOS		1,120		1,240		847	507		1,260			951		1,500	
	2		OOS		1,190		1,740		1,210	678		1,600			1,450			
	3		OOS		1,620		1,790		1,250	1,110		1,320			1,120		1,300	
	4		OOS		1,380		1,600		946	608		1,090			1,020			
2003	1		OOS		1,390		1,690		901	871		1,220			1,190	300	1,300	
	2		OOS		1,600		1,680		871	770		1,390			1,320			
	3		OOS		1,010		1,500		823	521		1,380			877		1,300	
	4	624	OOS		1,260		1,500		743	686		1,320			1,210			
2004	1		OOS		1,370		1,300		772	312		1,280			986			
	2		OOS															
	3		OOS		951		1,090		795			946			1,080			
Key		Analysis was performed, but tritium was not detected.																
		Tritium was detected (pCi/L).																
		If more than one positive detection occurred in a single quarter, then only the highest concentration is listed.																
		Note: MCL = 20,000 pCi/L FY = fiscal year MCL = maximum contaminant level OOS = out of service. Well rendered inoperable after attempts at repairs were unsuccessful																

Figure 3-24. Occurrences of tritium detections in the aquifer since Fiscal Year 1997.

FY 2004 are available and shown in Figure 3-24. Tritium detections above background primarily occur northeast of the SDA; however, in FY 2003, tritium was detected at low concentrations in two wells south of the SDA. The two wells, OW-2 and A11A31, are located approximately 1.0 and 1.5 mi south of the SDA, respectively. Subsequent samples collected from these two monitoring wells have not shown positive detections for tritium.

Table 3-22. Tritium detected above aquifer background concentrations.

Radionuclide	Sample Date	Well	Sample Result $\pm 1\sigma$ (pCi/L)	MDC (pCi/L)	Aquifer Background <sup>a</sup> (pCi/L)	MCL <sup>b</sup> (pCi/L)
Tritium	12/02/03	M3S	<b>1,280 <math>\pm</math> 114<sup>c</sup></b>	319	0–40	20,000
Tritium	12/01/03	M7S	<b>986 <math>\pm</math> 111<sup>c</sup></b>	325	0–40	20,000
Tritium	12/01/03	M12S	<b>1,370 <math>\pm</math> 112<sup>c</sup></b>	311	0–40	20,000
Tritium	12/01/03	M14S	<b>1,300 <math>\pm</math> 108<sup>c</sup></b>	298	0–40	20,000
Tritium	12/01/03	M16S	<b>772 <math>\pm</math> 107<sup>c</sup></b>	321	0–40	20,000
Tritium	12/03/03	M17S	<b>312 <math>\pm</math> 91<sup>c</sup></b>	292	0–40	20,000
Tritium	04/27/04	M3S	<b>946 <math>\pm</math> 87<sub>J</sub><sup>c</sup></b>	240	0–40	20,000
Tritium	05/05/04	M7S	<b>1,080 <math>\pm</math> 94<sub>J</sub><sup>c</sup></b>	257	0–40	20,000
Tritium	04/26/04	M12S	<b>951 <math>\pm</math> 127<sub>J</sub><sup>c</sup></b>	376	0–40	20,000
Tritium	04/26/04	M14S	<b>1,090 <math>\pm</math> 93<sub>J</sub><sup>c</sup></b>	253	0–40	20,000
Tritium	05/04/04	M16S	<b>731 <math>\pm</math> 85<sub>J</sub><sup>c</sup></b>	246	0–40	20,000
Tritium	05/04/04	M16S	<b>795 <math>\pm</math> 90<sub>J</sub><sup>c</sup></b>	259	0–40	20,000

a. The USGS established the SRPA background ranges in 1992 from samples collected upgradient (i.e., Mud Lake area) and downgradient (i.e., Magic Valley area) of the INL (Knobel, Orr, and Cecil 1992).

b. The MCLs are from the “National Primary Drinking Water Regulations” (40 CFR 141) established by the EPA.

c. **Black bold font** indicates sample concentrations less than the MCL, but exceeding aquifer background concentrations (see Footnote a). The “J” qualifier flags were assigned to the April and May 2004 results to denote a possible high bias because of unacceptable performance evaluation sample results for tritium. These reported concentrations should only be used as estimated quantities.

EPA = U.S. Environmental Protection Agency

MCL = maximum contaminant level

SRPA = Snake River Plain Aquifer

INL = Idaho National Laboratory

MDC = minimum detectable concentration

USGS = United States Geological Survey

### 3.4.4 Vapor Monitoring Results

Between 1970 and 1993, irradiated reactor beryllium reflector waste from the Advanced Test Reactor, Engineering Test Reactor, and the Materials Test Reactor was buried in the SDA. Beryllium in reactors undergoes (n,2n) and (n,α) reactions, generating substantial amounts of He-4 and tritium. The accumulation of helium and hydrogen atoms causes the beryllium to swell, so beryllium reflector blocks needed to be replaced periodically. Activated beryllium disposals contain a substantial fraction of the total C-14 in the RWMC inventory and practically the entire RWMC tritium inventory. The most recent disposal of beryllium consisted of six Advanced Test Reactor reflector blocks buried in SVR 20. These six blocks contain approximately 114,800 Ci of tritium (predominantly as <sup>3</sup>H<sub>2</sub>, corrected for decay to September 2001) and about 12 Ci of C-14 (Mullen et al. 2003). Tritium and C-14 are released from the beryllium by corrosion.

### 3.4.5 Sampling at Soil Vault Rows 12 and 20

**3.4.5.1 Ambient Air Sampling.** A substantial amount of tritium released from waste migrates to the atmosphere. Continuous sampling for airborne tritium was conducted at SVR 20 from 1995–2002. Measurements during 1994 and 1995 showed that the tritium concentration in air above SVR 20 ranges

over several orders of magnitude during the year, with peak concentrations occurring in late summer. Additional sampling is conducted during summer and fall with passive airborne tritium samplers to develop more detailed release information. Results from the two sampling methods show similar temporal fluctuations, but results are not directly comparable because the passive samplers are exposed to higher air concentrations than the environmental monitoring sampler.

Estimated annual emissions of tritium from buried activated beryllium at SVR 20 for Calendar Year (CY) 1995 through 2003 are shown in Table 3-23. These data are used to develop emission estimates by CY for all buried beryllium as required by the “National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities” (40 CFR 61, Subpart H).

Table 3-23. Estimated annual emission of tritium to air from buried activated beryllium at Soil Vault Row 20.

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Emission (Ci) <sup>a</sup>	30	30	3	0.5	3	20	10	10	5	2

a. Results for CY 1995–1999 are based on environmental monitoring sampling and results for CY 2000–2003 are based on the passive sampling results.  
CY = calendar year

**3.4.5.2 Soil Gas Sampling at SVR 20.** Monitoring tritium in soil gas samples at SVR 20 has been conducted since 1995. The ports were removed in FY 2004 to allow for grouting of the beryllium blocks, and the last of the soil gas samples at SVR 20 were collected in March 2004. Data leading up to the port removals showed increasing concentrations of tritium at an increasing rate through the active monitoring period. The concentration of tritium in soil 2.7 m (8.9 ft) deep is consistently greater than the concentrations measured at 4.5 and 6.3-m (15 and 21-ft) depth, but the concentrations at all depths fluctuate similarly and have the same general long-term trend.

Tritium concentrations at 2.7 m (8.9 ft) bls since 1996 are shown in Figure 3-25.<sup>g</sup> Generally, the highest concentrations observed each year occurred in the late summer (not shown); concentrations increased by about an order of magnitude each year.

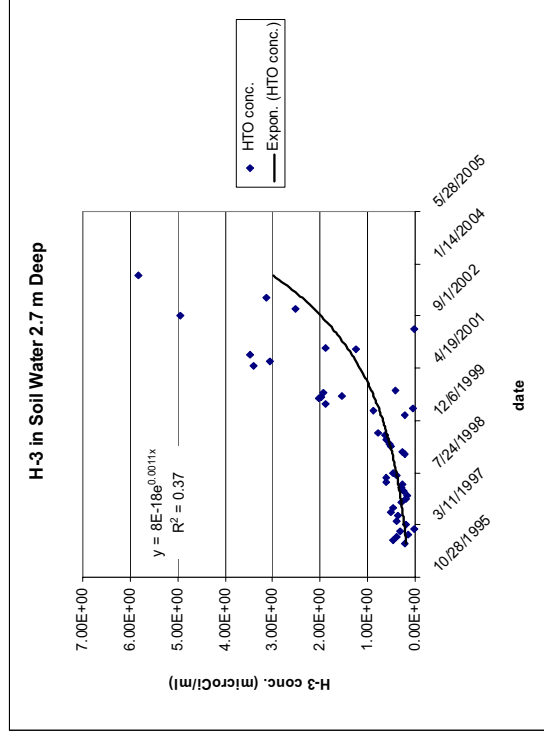


Figure 3-25. Concentration of tritium in soil moisture from 9 ft below land surface at SVR 20.

g. In Figure 3-25, an exponential equation was fit to the data, although there is no physical reason to assume that the exponential equation will fit over all time periods.

**3.4.5.3 Distribution of Volatile Tritium in the Vadose Zone.** The distribution of volatile tritium throughout the vadose zone at and around the SDA was examined in FY 2004. Vapor samples were collected from existing OCVZ monitoring ports at depths from 8.5–154 m (28–505 ft) to evaluate vapor phase transport of tritium in the vadose zone (see Table 3-24 and Figure 3-26).

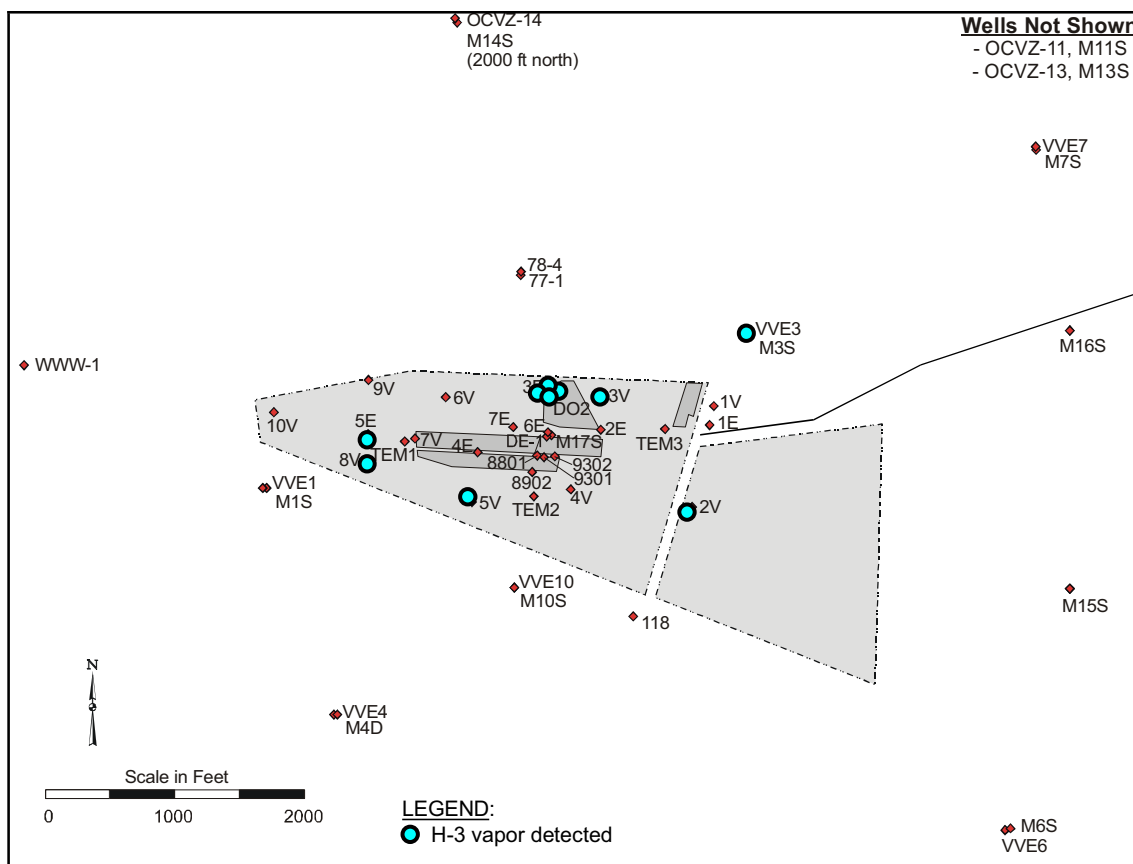
Table 3-24. Wells and vapor ports sampled for tritium and tritium concentrations from Radioactive Waste Management Complex vadose zone vapor samples for Fiscal Year 2004.

Sample Vapor Port Location	Likely Source of Tritium	Sample Depth (ft)	Vapor Concentration (pCi/g)	Lysimeter Well Nearest to Vapor Port Location	Soil-Moisture Concentration at Lysimeter Well (pCi/L)
2V LINE 2	Trenches 52 and 57, deep vapor phase transport of tritium to the aquifer	147	62.2	O-8	No samples
3V LINE 3	Release of tritium from Pit 5 and migration to lysimeters in Well TW-1. Deep vapor phase transport of tritium to the aquifer	47	0.9	W09	375
5E LINE 2	SVR 17 and Trench 58	50	5.8	I-2S	584
5V LINE 3	Trench 28	49	2.7	None	—
8V LINE 4	SVR 17 and Trench 58	57	1.4	I-2S	584
DO2 LINE 3	Release of tritium from Pit 5 and migration to lysimeters in Well TW-1.	166	0.5	TW1	1,770
DO2 LINE 5	Deep vapor phase transport of tritium to the aquifer	100	0.9	TW1	1,770
DO2 LINE 7		66	21.6	TW1	1,770
DO2 LINE 8		28	21.6	TW1	1,770
M3S LINE 2	Deep vapor phase transport of tritium to the aquifer in the northeast corner of the SDA	505	2.7	M3S	1,320

SDA = Subsurface Disposal Area  
SVR = soil vault row

Vapor samples were collected using a pump that pulled gas from existing OCVZ vapor ports through an absorbing media. This method relies on the condensation of soil moisture extracted from the wells by drawing a partial vacuum on each port and directing the gas flow into a fluid trap immersed in ice water brine. Water condenses inside the trap when its temperature is lower than that of the gas exiting the well. A portion of the trapped condensate is added to a liquid scintillation cocktail and analyzed at the laboratory using liquid scintillation counting. Because the pore water and the soil gas water vapor can be assumed to be at equilibrium with respect to tritium (Knight 1996), the trapped water has a tritium activity directly proportional to that of the pore water at the open interval of the well. Vapor results are reported in Table 3-24 in units of tritium activity per unit mass of condensed water, along with concentrations of soil moisture collected from nearby lysimeter wells. The soil-moisture samples were collected by OU 7-13/14 during routine monitoring in August 2004.





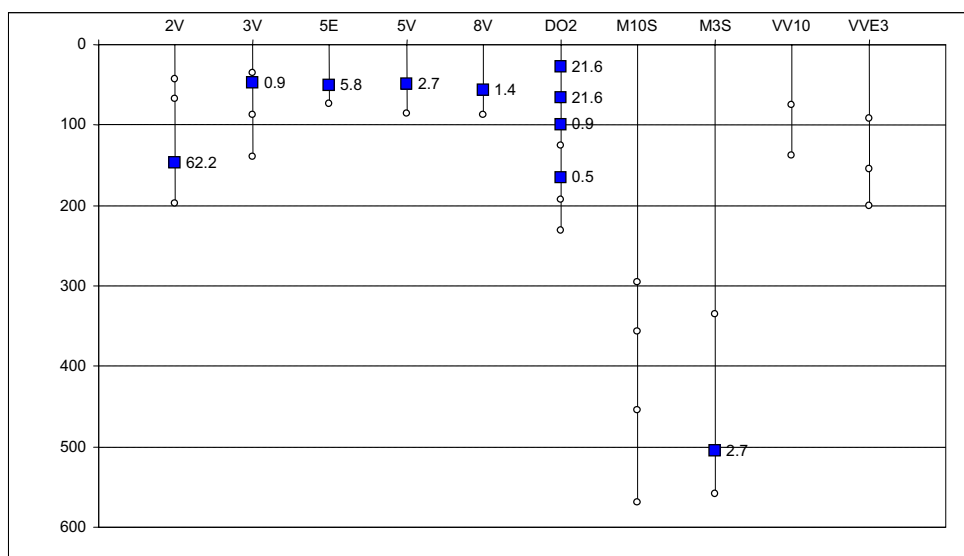


Figure 3-27. Tritium gas-sampling locations (open circles) and concentrations (pCi/g) of samples (blue squares) that exceeded background levels.

### 3.4.6 Summary of Tritium

Tritium is not a COPC; however, it is a mobile contaminant that co-occurs with activation products that are of concern (e.g., C-14 and Tc-99). Thus, tritium monitoring provides trend detection and early warning. In addition, a substantial fraction of tritium released from waste migrates to the atmosphere each year.

In the aquifer beneath the RWMC, tritium is consistently measured in six monitoring wells and is consistently absent in the other wells. Tritium concentrations in these six wells are gradually decreasing, and the decrease appears to correlate with the calculated rate of radioactive decay (see Figure 3-28, M7S RWMC example); however, it does not correlate with expected influences from dilution and dispersion. Under normal conditions, an initial pulse of tritium decayed, dispersed, and diffused over time would decrease much more rapidly (see Figure 3-28, USGS-65 Reactor Technology Complex [RTC] example). It could be that tritium is being added to the aquifer at a rate that exceeds decay effects. Tritium is not detected downgradient of the RWMC, and the general pattern of tritium occurrence around RWMC area wells is not yet understood.

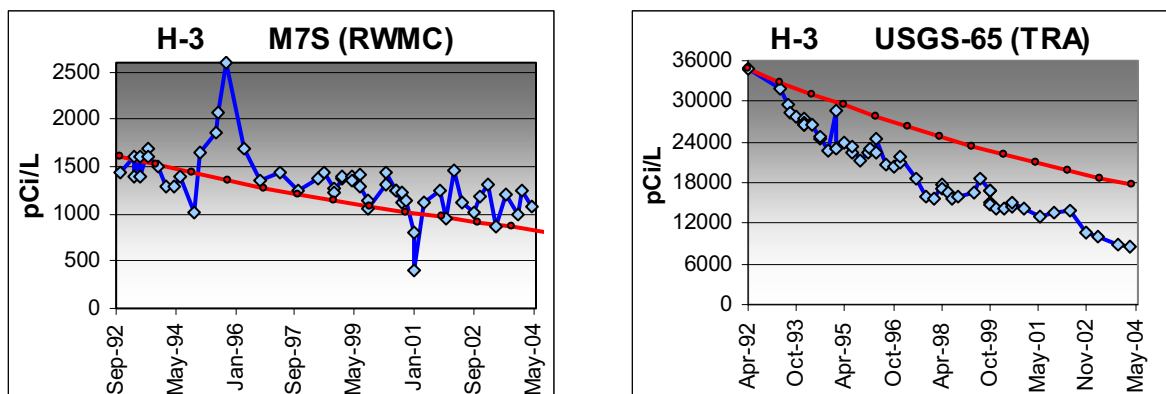


Figure 3-28. Comparison of tritium concentration time histories showing the observed effects of radioactive decay (—) and dilution and dispersion (Reactor Technology Complex well); and the observed effects of radioactive decay (—) with no apparent dilution and dispersion (Radioactive Waste Management Complex well).

The clear pattern of tritium detections and nondetections in RWMC area wells suggests that tritium might be a good radionuclide to compare with modeling results; however, the source term is difficult to define. Tritium has been injected into the aquifer at the RTC and INTEC, and tritium has migrated through both the vapor phase and infiltrating water in the vadose zone at the SDA. Quantifying and tracking these varied inputs, while also accounting for complex source-release rates and adjusting for decay, could result in large uncertainties that diminish the effort.

Tritium has been detected in numerous lysimeters and perched water wells in the SDA. Low-level detections occur in the shallow, intermediate, and deep regions of the vadose zone, and are fairly widespread throughout the SDA (see Figure 3-29). Tritium concentrations in the shallow vadose zone (i.e., 0–11 m [0–35 ft]) currently average about 650 pCi/L; at the intermediate depths (i.e., 11–43 m [35–140 ft]), the average is approximately 1,000 pCi/L; and the average in the deep interval 43–76 m (140–250 ft) is around 700 pCi/L. There have been no positive detections at lysimeter depths greater than 76 m (250 ft). Tritium detections in deeper regions of the vadose zone seem to be occurring more frequently. Since October 2003, tritium has been detected in Lysimeter Wells I2D (60 m [196 ft]), IE6 (66 m [215 ft]), IE8 (68 m [224 ft]), TW1 (69 m [227 ft]), and in Perched Water Wells D-10 (62 m [205 ft]), USGS-092 (65 m [214 ft]) and 8802D (67 m [220 ft]) at concentrations from about 200 to 1,700 pCi/L. Most tritium in the SDA is from the highly irradiated beryllium blocks buried in the SVRs. Tritium and C-14 have been monitored around SVR 20 since 1996. Results show that air sample concentrations are highly variable over the year, ranging several orders of magnitude, and peaking in late summer. Other temporal trends are not evident. In soil vapor samples near SVR 20, tritium concentrations have increased exponentially over time. Estimated emissions of tritium from buried activated beryllium at SVR 20 for CY 2004 were 2 Ci. Beryllium blocks were grouted in the Fall of 2004 to mitigate further spread and migration of C-14; alternatively, the grout will also help control the release of tritium into the environment. Maximum concentrations of tritium in vadose zone soil moisture and perched water since October 1997 are shown in Table 3-25. Maximum concentrations of tritium in the RWMC aquifer since October 1997 are shown in Table 3-26.

Table 3-25. Summary of maximum concentrations of tritium in vadose zone soil-moisture and perched water samples at the Radioactive Waste Management Complex from Fiscal Year 1997 through 2004.<sup>a</sup>

Sampling Range (ft bls)	Fiscal Year <sup>b</sup>	Maximum Concentration $\pm 1\sigma$ (pCi/L) <sup>c</sup>	Sample Location
Lysimeters 0–35 ft	1997	3,270 $\pm$ 100	W06:L27
	1998	7,290 $\pm$ 474	W06:L27
	1999	8,650 $\pm$ 554	W06:L27
	2000	9,100 $\pm$ 1,180	W06:L27
	2001	NA	—
	2002	NA	—
	2003	368 $\pm$ 77	PA02:L16
	2004	10,200 $\pm$ 802	PA01:L15
Lysimeters 35–140 ft	1997	NA	—
	1998	2,520 $\pm$ 249	TW1:DL04
	1999	2,950 $\pm$ 209	TW1:DL04
	2000	NA	—
	2001	NA	—
	2002	NA	—
	2003	1,690 $\pm$ 178	TW1:DL04
	2004	1,770 $\pm$ 89	TW1:DL04

Table 3-25. (continued).

Sampling Range (ft bls)	Fiscal Year <sup>b</sup>	Maximum Concentration $\pm 1\sigma$ (pCi/L) <sup>c</sup>	Sample Location
Lysimeters >140 ft	1997	NA	—
	1998	NA	—
	1999	NA	—
	2000	NA	—
	2001	NA	—
	2002	NA	—
	2003	ND	O7D:DL27, DE-06
	2004	1,680 $\pm$ 101	TW1-DL03
Perched water wells >140 ft	1997	310 $\pm$ 35	USGS-092
	1998	314 $\pm$ 56	USGS-092
	1999	1,570 $\pm$ 188	USGS-092
	2000	ND	USGS-092
	2001	NA	—
	2002	ND	USGS-092
	2003	ND	USGS-092
	2004	628 $\pm$ 63	D10

a. MCL = 20,000 pCi/L

b. Fiscal year spans from October 1 to September 30 (e.g., FY 1997 is October 1, 1996, to September 30, 1997).

c. NA = not analyzed ND = not detected

FY = fiscal year

MCL = maximum contaminant level

USGS = United States Geological Survey

Table 3-26. Summary of maximum concentrations of tritium in aquifer wells at the Radioactive Waste Management Complex from Fiscal Year 1997 through 2004.<sup>a</sup>

Fiscal Year <sup>b</sup>	Maximum Concentration $\pm 1\sigma$ (pCi/L)	Well Location
1997	1,910 $\pm$ 182	M3S
1998	1,990 $\pm$ 270	M12S
1999	1,860 $\pm$ 247	M14S
2000	1,860 $\pm$ 177	M14S
2001	1,730 $\pm$ 192	M14S
2002	1,740 $\pm$ 148	M14S
2003	1,690 $\pm$ 121	M14S
2004	1,370 $\pm$ 112	M12S

a. MCL = 20,000 pCi/L

b. Fiscal year spans from October 1 to September 30 (e.g., FY 1997 is October 1, 1996, to September 30, 1997).

FY = fiscal year

MCL = maximum contaminant level

### 3.5 Iodine-129

Iodine-129 is produced from nuclear reactor operations and weapons testing, and it occurs naturally in the environment through interactions of cosmic rays with atmospheric gases and from the spontaneous fission of U-238. Approximately 0.14 Ci of I-129 was buried in the SDA, according to inventory estimates through 1999, primarily from INL reactor operations waste.

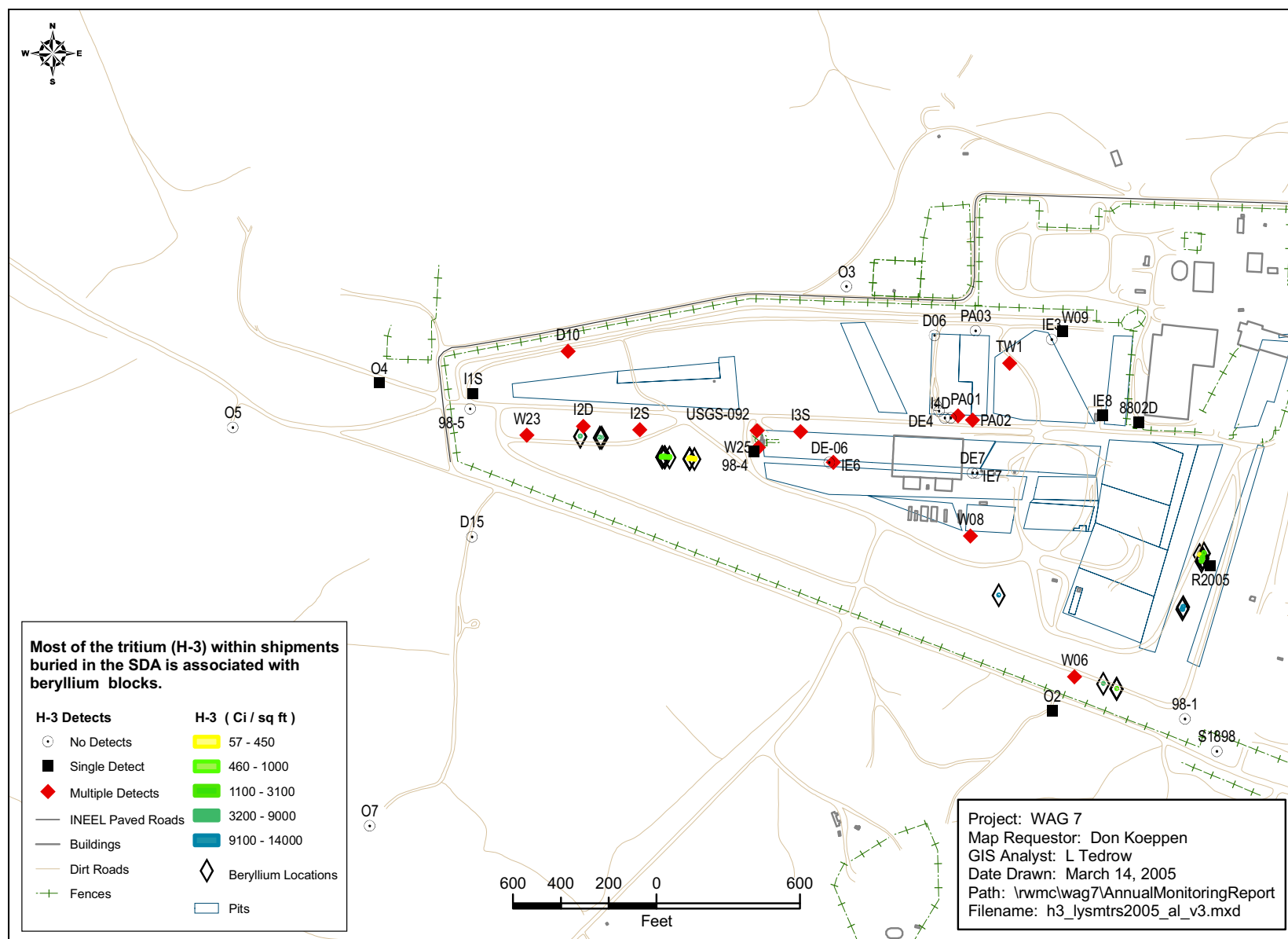


Figure 3-29. Tritium disposal locations and vadose zone detection locations at the Subsurface Disposal Area since 1997.

### 3.5.1 Waste Zone

Eighteen waste zone lysimeters were sampled every quarter in FY 2004. Lysimeters 741-08-L1 and 743-18-L2, located in Pits 10 and 4, respectively, were the only waste zone lysimeters to yield samples. Unfortunately, the volumes obtained were very small, permitting analysis for uranium isotopes, plutonium isotopes, Am-241, and gamma-emitting radionuclides, but not sufficient for I-129 analysis.

### 3.5.2 Vadose Zone

**NOTE:** *Detecting I-129 in soil-moisture samples is complicated by the high detection limits (40 pCi/L for 50-mL samples) and drawing the lysimeter sample with a vacuum, which may volatilize some I-129 from the media.*

**3.5.2.1 Lysimeter Samples at Depths from 0–35 ft.** Thirteen I-129 analyses were performed on soil-moisture samples collected from eight shallow lysimeters in and around the SDA in FY 2004, with no positive detections. Occurrences of I-129 detections in the shallow vadose-zone samples, since routine monitoring began in 1997, are summarized in Figure 3-30.

Since monitoring began, only three positive results have been observed in soil-moisture samples collected from the vadose zone.

**3.5.2.2 Lysimeter Samples from 35–140 ft Deep.** Thirteen I-129 analyses were performed on soil-moisture samples collected from nine intermediate-depth lysimeters in and around the SDA in FY 2004, with no positive detections. No I-129 has been detected in intermediate-depth lysimeter samples since 1997; therefore, a figure showing occurrences is not presented.

**3.5.2.3 Lysimeter and Perched Water Samples at Depths Greater than 140 ft.** Twenty-four I-129 analyses were performed on soil-moisture samples collected from 10 lysimeters and two perched water wells in FY 2004, with no positive detections. No I-129 has been detected in any wells or lysimeters from this depth range since sample collection began in 1997; therefore, a figure showing occurrences is not presented.

**3.5.2.4 Interbed Core Samples at Depths from 100–250 ft.** Thirteen I-129 analyses were performed on interbed core samples collected from five wells drilled in the SDA during FY 2004, with no positive detections. The wells sampled and analyzed for I-129 were Wells DE-3, DE-4, DE-6, DE-7, and DE-8 (see Figure 2-6). Other core investigations have been conducted at the SDA, and between 1994 and 2000, 52 core samples were collected for I-129 analysis, with no positive detections.

### 3.5.3 Aquifer

Forty-seven I-129 analyses were performed on aquifer samples collected from 15 monitoring wells in the vicinity of the RWMC in FY 2004, with no positive detections. Samples collected during the third quarter were analyzed at low detection limits (i.e., 0.1 pCi/L) to reconfirm that very low concentrations of I-129 are not present in the aquifer around the RWMC. Iodine-129 has not been detected in any aquifer wells since October 1998 (see Figure 3-31). At the end of 2004, the frequency at which the RWMC aquifer was monitored changed to biannually; thus only data from the first three quarters of FY 2004 are available and shown in Figure 3-31.

		Iodine-129 Radioactive Waste Management Complex Lysimeters (0–35 ft)															
FY	Qtr	98-1: L35	98-4: L38	98-5: L39	D15: DL07	PA01: L15	PA02: L16	PA03: L33	W05: L25	W06: L27	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
1997	1																
	2																
	3																
	4																
1998	1																
	2																
	3																
	4																
1999	1	53		29													
	2																
	3																
	4																
2000	1																
	2																
	3																
	4																
2001	1																
	2																
	3																
	4																
2002	1																
	2																
	3																
	4																
2003	1																
	2																
	3																
	4																
2004	1																
	2																
	3																
	4																
Key		Analysis was performed, but I-129 was not detected.															
		I-129 was detected (pCi/L).															

Figure 3-30. Occurrences of iodine-129 detections in shallow lysimeter wells since 1997.

		Iodine-129 Radioactive Waste Management Complex Aquifer-Monitoring Wells															
FY	Qtr	A11-A31	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	M1S	M3S	M4D	M6S	M7S	OW2	USGS-127
1997	1																
	2																
	3		1.7														
	4																
1998	1													0.59			
	2																
	3																
	4										0.98						
1999	1														1.5		
	2																
	3																
	4																
2000	1																
	2																
	3																
	4																
2001	1																
	2		OOS														
	3		OOS														
	4		OOS														
2002	1		OOS														
	2		OOS														
	3		OOS														
	4		OOS														
2003	1		OOS														
	2		OOS														
	3		OOS														
	4		OOS														
2004	1		OOS														
	2		OOS														
	3		OOS														
Key		Analysis performed, but I-129 was not detected.															
		I-129 was detected (pCi/L).															
		If more than one positive detection occurred in a single quarter, then only the highest concentration is listed.															
		Note: MCL = 1 pCi/L FY = fiscal year MCL = maximum contaminant level OOS = out of service															

Figure 3-31. Occurrences of iodine-129 detections in Radioactive Waste Management Complex aquifer wells since 1997.



### 3.5.4 Summary of Iodine-129

No I-129 was detected in soil-moisture samples or interbed sediment samples collected in FY 2004 from the SDA vadose zone or from water samples collected from RWMC aquifer-monitoring wells. Tables 3-27 and 3-28 summarize the maximum I-129 concentrations detected in vadose zone and aquifer samples since FY 1997, respectively. Three historical detections in the vadose zone and perched water are not indicative of trends. Figure 3-32 depicts historical I-129 detections with the known I-129 disposal locations. The detection of I-129 in soil moisture from Lysimeter 98-1L35, at a depth of 5 m (16.5 ft), is the only detection that occurred near a mapped disposal location. The three lone detections depicted in Figure 3-32 were not substantiated in later sampling events. An independent study, conducted in May 2003, of 38 aquifer wells that reside in the region between the RTC, Idaho Nuclear Technology Engineering Center, Central Facilities Area, and RWMC, and the low-level analysis performed on RWMC aquifer samples in the third quarter of this fiscal year, provides evidence that I-129 is not present above method detection limits (0.1 pCi/L) in the aquifer in or around the RWMC.

Table 3-27. Summary of maximum concentrations of iodine-129 in vadose zone soil-moisture and perched water samples at the Radioactive Waste Management Complex from Fiscal Year 1997 through 2004.<sup>a</sup>

Sampling Range (ft bls)	Fiscal Year <sup>b</sup>	Maximum Concentration $\pm 1\sigma$ (pCi/L) <sup>c</sup>	Sample Location
Lysimeters 0–35 ft	1997	ND	Various <sup>d</sup>
	1998	ND	Various <sup>d</sup>
	1999	53 $\pm$ 18	98-1:L35
	2000	22 $\pm$ 7	W25:L28
	2001	NA	—
	2002	NA	—
	2003	ND	Various <sup>d</sup>
	2004	ND	Various <sup>d</sup>
Lysimeters 35–140 ft	1997	ND	D06:DL02
	1998	ND	Various <sup>d</sup>
	1999	NA	—
	2000	NA	—
	2001	NA	—
	2002	NA	—
	2003	ND	Various <sup>d</sup>
	2004	ND	Various <sup>d</sup>
Lysimeters >140 ft	1997	NA	—
	1998	NA	—
	1999	NA	—
	2000	NA	—
	2001	NA	—
	2002	NA	—
	2003	ND	DE-06
	2004	ND	Various <sup>d</sup>

Table 3-27. (continued).

Sampling Range (ft bls)	Fiscal Year <sup>b</sup>	Maximum Concentration $\pm 1\sigma$ (pCi/L) <sup>c</sup>	Sample Location
Perched water wells >140 ft	1997	ND	USGS-92
	1998	ND	8802D
	1999	ND	USGS-92
	2000	NA	—
	2001	NA	—
	2002	ND	USGS-92
	2003	ND	USGS-92
	2004	ND	8802D

a. MCL = 1 pCi/L

b. Fiscal year spans from October 1 to September 30 (e.g., FY 1997 is October 1, 1996, to September 30, 1997).

c. NA = not analyzed ND = not detected

d. Various locations were sampled.

FY = fiscal year

MCL = maximum contaminant level

Table 3-28. Summary of maximum concentrations of iodine-129 in aquifer wells at the Radioactive Waste Management Complex from Fiscal Year 1997 through 2004.<sup>a</sup>

Fiscal Year <sup>b</sup>	Maximum Concentration $\pm 1\sigma$ (pCi/L)	Well Location
1997	1.7 $\pm$ 0.4	M10S
1998	1.0 $\pm$ 0.2	M1S
1999	1.5 $\pm$ 0.4	M7S
2000	ND <sup>c</sup>	Various <sup>d</sup>
2001	ND <sup>c</sup>	Various <sup>d</sup>
2002	ND <sup>c</sup>	Various <sup>d</sup>
2003	ND	Various <sup>d</sup>
2004	ND	Various <sup>d</sup>

a. MCL = 1 pCi/L

b. Fiscal year spans from October 1 to September 30 (e.g., FY 1997 is October 1, 1996, to September 30, 1997).

c. ND = not detected

d. Various locations were sampled.

FY = fiscal year

MCL = maximum contaminant level

## 3.6 Neptunium-237

Neptunium-237 is a TRU isotope, which is a product of nuclear reactor operations and is a decay product of Am-241. Approximately 0.12 Ci of Np-237 was buried in the SDA, according to inventory estimates through 1999, and approximately 39 Ci of Np-237 is expected to be produced over 1,000 years from the radioactive decay of Pu-241.

### 3.6.1 Waste Zone

Eighteen waste zone lysimeters were sampled every quarter in FY 2004. Lysimeters 741-08-L1 and 743-18-L2, located in Pits 10 and 4, respectively, were the only waste zone lysimeters to yield samples. Unfortunately, the volumes obtained were very small, permitting analysis for TRU and gamma-emitting radionuclides, but not sufficient for Np-237 analysis.

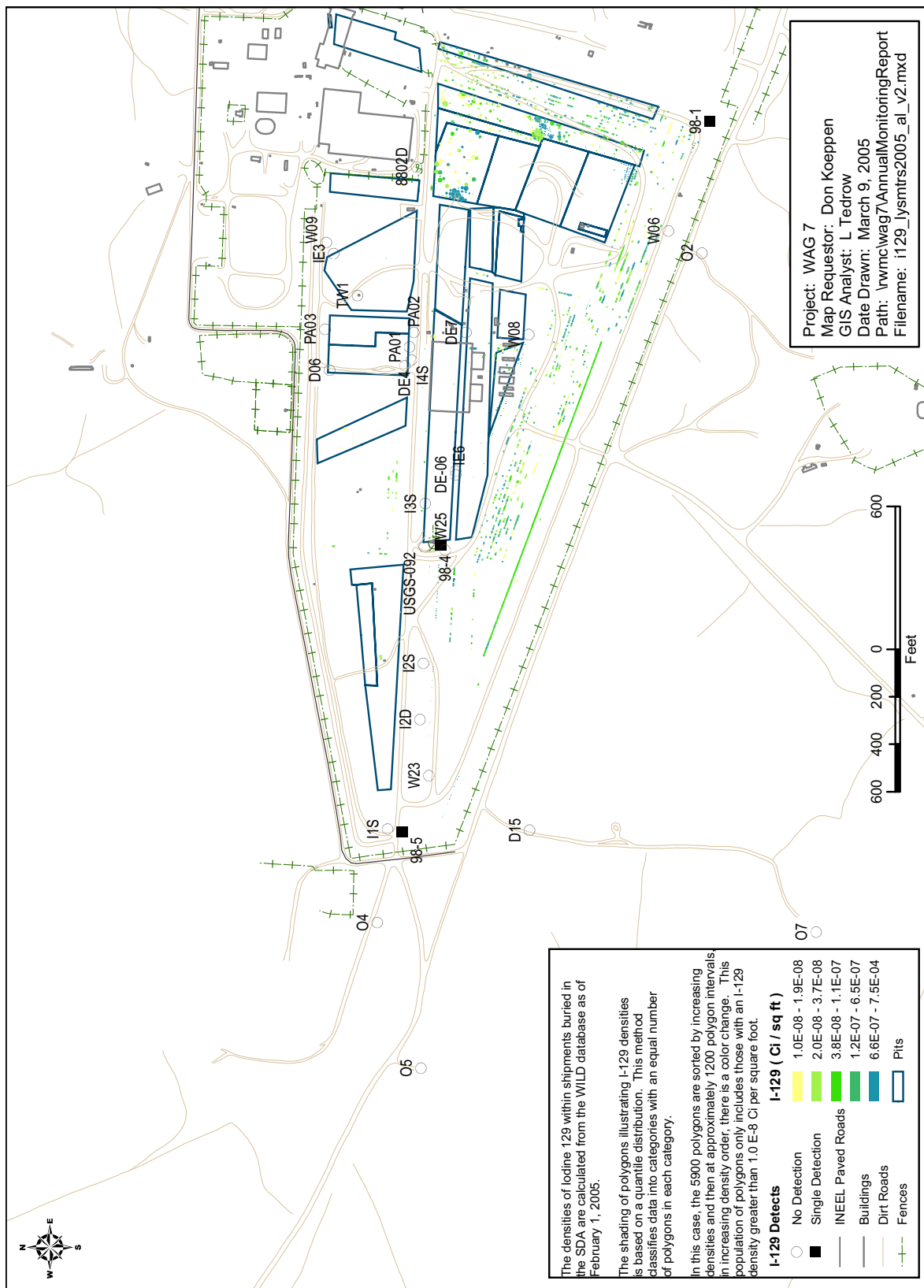


Figure 3-32. Iodine-129 disposal locations and vadose zone detection locations at the Subsurface Disposal Area.

### **3.6.2 Vadose Zone**

#### **3.6.2.1 Subsurface Soil Samples Collected While Drilling Lysimeter Well RWMC-2005.**

In April 2004, while drilling Well RWMC-2005 in the east end of the SDA (see Figure 2-3), radioactivity above background was detected in the drilling soil returns. Drilling was stopped, and three separate soil samples were collected from these returns. The samples were analyzed for Np-237, and none was detected.

**3.6.2.2 Lysimeter Samples from 0–35 ft Deep.** Thirteen Np-237 analyses were performed on soil-moisture samples collected from eight shallow lysimeters in and around the SDA in FY 2004, with no positive detections. No Np-237 has been detected in shallow lysimeter samples since monitoring began in FY 2000; therefore, a figure showing occurrences is not presented.

**3.6.2.3 Lysimeter Samples from 35–140 ft Deep.** Eleven Np-237 analyses were performed on soil-moisture samples collected from seven intermediate-depth lysimeters in and around the SDA in FY 2004, with no positive detections. No Np-237 has been detected in intermediate-depth lysimeter samples since monitoring began in FY 2000; therefore, a figure showing occurrences is not presented.

**3.6.2.4 Lysimeter and Perched Water Samples Deeper than 140 ft.** Seventeen Np-237 analyses were performed on samples collected from nine lysimeters and one perched water well in and around the SDA in FY 2004, with no positive detections. No Np-237 has been detected in any samples collected at this depth interval since monitoring began in FY 2000; therefore, a figure showing occurrences is not presented.

**3.6.2.5 Interbed Core Samples at Depths from 100–250 ft.** Thirteen Np-237 analyses were performed on interbed core samples collected from five wells drilled in the SDA during FY 2004, with no positive detections. Historical core investigations have not analyzed for Np-237.

### **3.6.3 Aquifer**

Forty-eight Np-237 analyses were performed on aquifer samples collected from 15 monitoring wells in the vicinity of the RWMC in FY 2004, resulting in one positive detection at a concentration near the method detection limit. The positive detection occurred in December 2003 from Well M11S (see Table 3-29). This is the first time a positive detection has occurred in Well M11S since Np-237 monitoring of the RWMC aquifer began in FY 1999, and no detections have occurred in this monitoring well since that time. Over the past 6 years, there have been four Np-237 detections out of 347 sample analyses performed on each of the 15 RWMC monitoring wells. Each detection was in a different well, and none of the detections were confirmed by reanalysis or subsequent sampling events; therefore, a figure showing occurrences is not presented.

### **3.6.4 Summary of Neptunium-237**

Neptunium-237 has not been detected in the vadose zone or perched water since monitoring began. One detection occurred in the waste zone sample in April 2002. In FY 2004, a low-level detection was observed in Aquifer Well M11S. That is the only occurrence when Np-237 was detected in Well M11S, and this provides insufficient information to declare Np-237 present in the aquifer at this locale. It will require many more monitoring events to determine the absence or presence of Np-237 in this monitoring well. Of 347 Np-237 sample analyses performed on RWMC aquifer samples since monitoring began in FY 1999, there have been only three other low-level detections, all of which occurred in separate aquifer wells, and none of which were confirmed by reanalysis or subsequent sampling events. This amounts to about a 1 percent detection rate, which is expected at the 99 percent confidence level. Core samples of the B-C and C-D interbeds were analyzed in 2004 and no Np-237 was detected in any of the samples. The data reside in the Environmental Data Warehouse. Tables 3-30 and 3-31 summarize the maximum Np-237 concentrations detected in vadose zone and aquifer samples since FY 1997, respectively.

Table 3-29. Neptunium-237 detected above aquifer background concentrations.

Radionuclide	Sample Date	Well	Sample Result $\pm 1\sigma$ (pCi/L)	MDC (pCi/L)	Aquifer Background <sup>a</sup> (pCi/L)	MCL <sup>b</sup> (pCi/L)
Np-237	12/01/03	M11S	<b>0.08 <math>\pm</math> 0.02<sup>c</sup></b>	0.05	0	15

a. The USGS established the SRPA background ranges in 1992 from samples collected upgradient (i.e., Mud Lake area) and downgradient (i.e., Magic Valley area) of the INL (Knobel, Orr, and Cecil 1992).

b. The MCLs are from the “National Primary Drinking Water Regulations” (40 CFR 141) established by the EPA. The MCL for Np-237 is based on total alpha.

c. **Black bold font** indicates sample concentrations less than the MCL, but exceeding aquifer background concentrations (see Footnote a). The “J” qualifier flags were assigned to the April and May 2004 results to denote a possible high bias because of unacceptable performance evaluation sample results for tritium. These reported concentrations should only be used as estimated quantities.

EPA = U.S. Environmental Protection Agency

INL = Idaho National Laboratory

MCL = maximum contaminant level

MDC = minimum detectable concentration

SRPA = Snake River Plain Aquifer

USGS = United States Geological Survey

Table 3-30. Summary of maximum concentrations of neptunium-237 in soil-moisture and perched water samples at the Radioactive Waste Management Complex from Fiscal Year 1997 through 2004.<sup>a</sup>

Sampling Range (ft bls)	Fiscal Year <sup>b</sup>	Maximum Concentration $\pm 1\sigma$ (pCi/L) <sup>c</sup>	Sample Location
Lysimeters 0–35 ft	1997	NA	—
	1998	NA	—
	1999	NA	—
	2000	ND	Various <sup>d</sup>
	2001	ND	Various <sup>d</sup>
	2002	6.1 $\pm$ 1.7	741-08-L1 (waste zone)
	2003	ND	Various <sup>d</sup>
	2004	ND	Various <sup>d</sup>
Lysimeters 35–140 ft	1997	NA	—
	1998	NA	—
	1999	NA	—
	2000	ND	Various <sup>d</sup>
	2001	ND	Various <sup>d</sup>
	2002	ND	Various <sup>d</sup>
	2003	ND	Various <sup>d</sup>
	2004	ND	Various <sup>d</sup>
Lysimeters >140 ft	1997	NA	—
	1998	NA	—
	1999	NA	—
	2000	NA	—
	2001	NA	—
	2002	NA	—
	2003	ND	Various <sup>d</sup>
	2004	ND	Various <sup>d</sup>

Table 3-30. (continued).

Sampling Range (ft bls)	Fiscal Year <sup>b</sup>	Maximum Concentration $\pm 1\sigma$ (pCi/L) <sup>c</sup>	Sample Location
Perched water wells >140 ft	1997	NA	—
	1998	NA	—
	1999	NA	—
	2000	ND	USGS-92
	2001	ND	USGS-92
	2002	ND	USGS-92
	2003	ND	USGS-92, 8802D
	2004	ND	USGS-92

a. MCL = 15 pCi/L total alpha activity concentration

b. Fiscal year spans from October 1 to September 30 (e.g., Fiscal Year 1997 is October 1, 1996, to September 30, 1997).

c. NA = not analyzed ND = not detected

d. Various locations were sampled.

MCL = maximum contaminant level

Table 3-31. Summary of maximum concentrations of neptunium-237 in aquifer wells at the Radioactive Waste Management Complex from Fiscal Year 1997 through 2004.<sup>a</sup>

Fiscal Year <sup>b</sup>	Maximum Concentration $\pm 1\sigma$ (pCi/L) <sup>c</sup>	Well Location
1997	NA	—
1998	NA	—
1999	ND	Various <sup>d</sup>
2000	ND	Various <sup>d</sup>
2001	ND	Various <sup>d</sup>
2002	0.38 $\pm$ 0.04	A11A31
2003	ND	Various <sup>d</sup>
2004	0.08 $\pm$ 0.02	M11S

a. MCL = 15 pCi/L total alpha activity concentration

b. Fiscal year spans from October 1 to September 30 (e.g., Fiscal Year 1997 is October 1, 1996, to September 30, 1997).

c. NA = not analyzed ND = not detected

d. Various locations were sampled.

MCL = maximum contaminant level

## 3.7 Niobium-94

Niobium-94 is a gamma-emitting radionuclide that is an activation product generated during nuclear reactor operations. Approximately 1.34E+02 Ci of Nb-94 was buried in the SDA, according to inventory estimates through 1999. Most of the Nb-94 inventory is in the form of reactor core components and end pieces from reactor cores. Some of the disposal inventory is contained in activated stainless steel and resins.

### 3.7.1 Waste Zone

Eighteen waste zone lysimeters were sampled every quarter in FY 2004, and Lysimeters 741-08-L1 and 743-18-L2, located in Pits 10 and 4, respectively, were the only waste zone lysimeters to yield samples. The sample volume was very small, but adequate to perform analysis for gamma-emitting radionuclides. Niobium-94 was not detected in any of the samples.

### 3.7.2 Vadose Zone

#### 3.7.2.1 *Subsurface Soil Samples Collected While Drilling Lysimeter Well RWMC-2005.*

In April 2004, while drilling Lysimeter Well RWMC-2005 in the east end of the SDA (see Figure 2-3), radioactivity above background was detected in the drilling returns. Drilling was stopped, and three separate soil samples were collected from these returns. Niobium-94 was not reported by the laboratory, because it was not specifically requested by the project. Fortunately, analytical protocol requires the laboratory to report any positive detection identified in the gamma analysis spectrum, even when the radionuclide is not targeted, and Nb-94 was not reported as being detected in the soil samples.

**3.7.2.2 *Lysimeter Samples from 0–35 ft Deep.*** Twenty-three Nb-94 analyses were performed on soil-moisture samples collected from nine shallow lysimeters in and around the SDA in FY 2004, with no positive detections. No Nb-94 has been detected in shallow lysimeter samples since monitoring for it began in January 2002; therefore, a figure showing occurrences is not presented.

**3.7.2.3 *Lysimeter Samples from 35–140 ft Deep.*** Thirty-nine Nb-94 analyses were performed on soil-moisture samples collected from 13 intermediate-depth lysimeters in and around the SDA in FY 2004, with no positive detections. No Nb-94 has been detected in intermediate-depth lysimeter samples since monitoring for it began in January 2002; therefore, a figure showing occurrences is not presented.

**3.7.2.4 *Lysimeter and Perched Water Samples Deeper than 140 ft.*** Sixty-one Nb-94 analyses were performed on samples collected from 17 lysimeters and three perched water wells in and around the SDA in FY 2004, with no positive detections. No Nb-94 has been detected in any samples collected at this depth interval since its monitoring began in January 2002; therefore, a figure showing occurrences is not presented.

### 3.7.3 Aquifer

Forty-nine gamma analyses were performed on aquifer samples collected from 15 monitoring wells in the vicinity of the RWMC in FY 2004, with no positive detections of Nb-94 noted. Reporting Nb-94 results were not specifically requested by the project, and therefore were not reported by the laboratory. Fortunately analytical protocol requires the laboratory to report any positive detection identified in the gamma analysis spectrum, even when the radionuclide is not targeted, and Nb-94 was not reported as being detected in any of the RWMC aquifer samples. Niobium-94 has never been reported as being detected in any aquifer samples since monitoring began; therefore, a figure showing occurrences is not presented.

### 3.7.4 Summary of Niobium-94

Niobium-94 has never been detected in the aquifer, vadose zone, or perched water since monitoring began. The limits of detection for large volume aquifer samples, using gamma spectrometry, are about 3 pCi/L, which are adequate to meet the aquifer 1E-05 RBC of 61.3 pCi/L. Detection limits for small volume soil-moisture samples are generally about 30 pCi/L, but can vary to about 100 pCi/L, depending on the volume. Because MCLs and RBCs are not applicable to soil moisture in the vadose zone, the analytical method is sufficient for project needs.

## 3.8 Plutonium

All plutonium isotopes are anthropogenic and TRU products of nuclear reactor operations or nuclear weapons production, deployment, and testing. Approximately 2.08E+03 Ci of Pu-238 was buried in the SDA, primarily from INL reactor operations waste. Approximately 6.41E+04 Ci of Pu-239,

primarily from RFP, was buried in the SDA. Approximately 1.46E+04 Ci of Pu-240 was buried in the SDA, primarily from RFP, with a significant portion from INL reactor operations. Listed inventories are estimates through 1999.

### 3.8.1 Waste Zone

Eighteen Type B waste zone lysimeters were sampled every quarter in FY 2004. Lysimeters 741-08-L1 and 743-18-L2, located in Pits 10 and 4, respectively, were the only waste zone lysimeters to yield samples. Plutonium-238 and Pu-239/240 analyses were performed on these samples, with two positive Pu-239/240 detections (see Table 3-32).

Table 3-32. Plutonium detections in Fiscal Year 2004 Subsurface Disposal Area waste zone samples.

Radionuclide	Sample Date	Well: Lysimeter	Lysimeter Depth (ft)	Sample Result $\pm 1\sigma$ (pCi/L)	MDC (pCi/L)	Local Soil Moisture Background (pCi/L)	RBC <sup>b</sup> (pCi/L)
Pu-239/240	06/22/04	743-18-L2	12.8	<b>46 ± 6<sup>c</sup></b>	2	0.0	3.53
Pu-239/240	09/14/04	743-18-L2	12.8	<b>21 ± 6<sup>c</sup></b>	11	0.0	3.53

a. The local soil moisture background concentration for tritium is essentially zero and defined as a nondetect (i.e., a result less than or equal to its MDA and less than or equal to three times its reported  $1\sigma$  uncertainty). Local soil-moisture background concentrations are established with lysimeter samples regularly collected from the "O" and D15-series lysimeter wells located outside of the SDA.

b. RBC = 1E-05 for drinking water. The RBCs for the aquifer are provided here as a basis of comparison.

c. **Red bold font** indicates sample concentrations that exceed the RBC (see Footnote b).

MDA = minimum detectable activity

MDC = minimum detectable concentration

RBC = risk-based concentration

SDA = Subsurface Disposal Area

### 3.8.2 Vadose Zone

#### 3.8.2.1 Subsurface Soil Samples Collected While Drilling Lysimeter Well RWMC-2005.

In April 2004, while drilling Lysimeter Well RWMC-2005 in the east end of the SDA (see Figure 2-3), radioactivity above background was detected in the drilling soil returns. Drilling was stopped and three separate soil samples were collected from these returns. The samples were analyzed for plutonium isotopes, and Pu-238 was detected in one of the samples (see Table 3-33).

Table 3-33. Plutonium detections in Fiscal Year 2004 Subsurface Disposal Area vadose zone soil sample.

Radionuclide	Sample Date	Well: Lysimeter	Lysimeter Depth (ft)	Sample Result $\pm 1\sigma$ (pCi/g)	MDC (pCi/g)	INL Soil Background UTL <sup>a</sup> (pCi/g)	Soil RBC <sup>b</sup> (pCi/g)
Pu-238	04/26/04	RWMC-2005	8.9	<b>0.051 ± 0.009<sub>J</sub><sup>c</sup></b>	0.020	0.009	29.2

a. INL surficial soil background 95% upper tolerance concentration limits for grab samples are not directly applicable to subsurface soils, but are provided here only as a basis for comparison. The surficial soil background tolerance limits were established in 1996 (Rood, Harris, and White 1996).

b. Calculated risk-based concentration (RBC) for soil is equivalent to an increased cancer of 1E-05.

c. **Black bold font** indicates sample concentrations less than the RBC, but exceeding surficial soil background upper tolerance limit (see Footnote a). The "J" flag was assigned to the Pu-238 result because of a small amount of Pu-238 contamination in the blank sample. The results are usable, but should only be used as estimated quantities.

MDC = minimum detectable concentration

RBC = risk-based concentration

UTL = upper 95% tolerance level with 95% confidence



**3.8.2.2 Lysimeter Samples at Depths of 0–35 ft.** Twenty-three Pu-238 and Pu-239/240 analyses were performed on soil-moisture samples collected from nine shallow lysimeters in and around the SDA in FY 2004, with no positive detections. Historical detections in shallow lysimeter samples are depicted in Figure 3-33 for Pu-238 and Figure 3-34 for Pu-239/240.

**3.8.2.3 Lysimeter Samples at Depths of 35–140 ft.** Thirty-six Pu-238 and Pu-239/240 analyses were performed on soil-moisture samples collected from 13 intermediate-depth lysimeters in and around the SDA in FY 2004, with no positive detections. Historical detections are shown in Figure 3-35 for Pu-238 and Figure 3-36 for Pu-239/240.

**3.8.2.4 Lysimeter and Perched Water Samples at Depths Greater than 140 ft.** Sixty-two Pu-238 and Pu-239/240 analyses were performed on samples collected from 20 lysimeters and three perched water wells in and around the SDA in FY 2004, with no positive detections. Historical detections are shown in Figure 3-37 for Pu-238 and Figure 3-38 for Pu-239/240.

**3.8.2.5 Interbed Cores Samples at Depths from 100–250 ft.** Thirteen Pu-238 and Pu-239/240 analyses were performed on interbed core samples collected from five wells drilled in the SDA during FY 2004, with no positive detections. Wells DE-3, DE-4, DE-6, DE-7 and DE-8 (see locations in Figure 2-6) were sampled and analyzed for plutonium. Other core investigations have been conducted at the SDA, and plutonium was detected. Between 1971 and 2000, 341 core samples were collected and analyzed for Pu-238, and 352 were analyzed for Pu-239/240, with 47 total detections. Concentration ranges detected in the vicinity of the interbeds are summarized in Table 3-34.

Table 3-34. Summary of previous plutonium detections in Subsurface Disposal Area vadose zone core samples from 1971 to 2000 (Holdren et al. 2002).

Interbed	Depth Interval (ft bls)	Concentration Range (pCi/g)	Plutonium Detection Rate (%)
B-C	98–113	0.003–0.74	11
C-D	230–240	0.013–0.14	2.9

### 3.8.3 Aquifer

Fifty-one Pu-238 and Pu-239/240 analyses were performed on aquifer samples collected from 15 monitoring wells in the vicinity of the RWMC in FY 2004, with two positive Pu-238 detections (see Table 3-35). The samples from Wells A11A31 and M4D were reanalyzed, and Pu-238 was not detected (see Table 3-35); therefore, the positive detections are unconfirmed. These detections are suspect, because Pu-238 has never been detected or confirmed to be present in these particular wells. The Pu-238 results at these low concentrations are probably false positive. Most false positives in alpha spectroscopy are generally due to incomplete separation of the target radionuclide from the interfering radionuclides. Natural Th-228 is the interferer that can cause false positive results of Pu-238 (Kubilius et al. 2004). Occurrences of Pu-238 and Pu-239/240 in aquifer samples since FY 1997 are depicted in Figures 3-39 and 3-40, respectively. At the end of 2004, the frequency at which the RWMC aquifer was monitored changed to biannually; thus only data from the first three quarters of FY 2004 are available and shown in Figures 3-39 and 3-40.

Plutonium-238 Radioactive Waste Management Complex Lysimeters (0–35 ft)																	
FY	Qtr	98-1: L35	98-4: L38	98-5: L39	D15: DL07	PA01: L15	PA02: L16	PA03: L33	W05: L25	W06: L27	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
1997	1																
	2																
	3																
	4							24									
1998	1																
	2							2.2									
	3			5.6		8.5											
	4																
1999	1																
	2																
	3																
	4																
2000	1																
	2																
	3																
	4		0.88			2.3											
2001	1						3.7										
	2																
	3																
	4																
2002	1																
	2																
	3																
	4																
2003	1																
	2																
	3																
	4																
2004	1																
	2																
	3																
	4																
Key		Analysis was performed, but Pu-238 was not detected.															
		Pu-238 was detected (pCi/L).															
		If more than one positive detection occurred in a single quarter, then only the highest concentration is listed.															
		Note: 1E-05 RBC = 3.64 pCi/L FY = fiscal year RBC = risk-based concentration RWMC = Radioactive Waste Management Complex															

Figure 3-33. Occurrences of plutonium-238 in shallow lysimeter samples since Fiscal Year 1997.

Plutonium-239/240 Radioactive Waste Management Complex Lysimeters (0–35 ft)																	
FY	Qtr	98-1: L35	98-4: L38	98-5: L39	D15: DL07	PA01: L15	PA02: L16	PA03: L33	W05: L25	W06: L27	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
1997	1																
	2																
	3																
	4																
1998	1																
	2																
	3																
	4																
1999	1																
	2																
	3																
	4																
2000	1																
	2																
	3																
	4																
2001	1																
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	3																
	4																
2002	1																
	2																
	3																
	4																
2003	1																
	2																
	3																
	4																
2004	1																
	2																
	3																
	4																
Key		Analysis was performed, but Pu-239/240 was not detected.															
		Pu-239/240 was detected (pCi/L).															
		If more than one positive detection occurred in a single quarter, then only the highest concentration is listed.															
		Note: 1E-05 RBC = 3.53 pCi/L FY = fiscal year RBC = risk-based concentration RWMC = Radioactive Waste Management Complex															

Figure 3-34. Occurrences of plutonium-239/240 detections in shallow lysimeters since Fiscal Year 1997.

		Plutonium-238 Radioactive Waste Management Complex Lysimeters (35–140 ft)													
FY	Qtr	D06: DL01	D06: DL02	D15: DL06	I-1S: DL09	I-2S: DL11	I-3S: DL13	I-4S: DL15	I-5S: DL16	O2: DL20	O3: DL22	O4: DL24	O5: DL25	O7: DL28	TW1: DL04
1997	1														
	2														
	3														
	4	11.6	3.3	3.1											
1998	1														
	2														
	3														
	4														
1999	1														
	2														
	3														
	4														
2000	1														
	2														
	3														
	4														
2001	1														
	2														
	3														
	4														
2002	1														
	2														
	3														
	4														
2003	1														
	2														
	3														
	4														
2004	1														
	2														
	3														
	4														
Key		Analysis was performed, but Pu-238 was not detected.													
		Pu-238 was detected (pCi/L).													
		If more than one positive detection occurred in a single quarter, then only the highest concentration is listed. Note: 1E-05 RBC = 3.64 pCi/L FY = fiscal year RBC = risk-based concentration RWMC = Radioactive Waste Management Complex													

Figure 3-35. Occurrences of plutonium-238 detections in intermediate-depth lysimeters since Fiscal Year 1997.

		Plutonium-239/240 Radioactive Waste Management Complex Lysimeters (35–140 ft)													
FY	Qtr	D06: DL01	D06: DL02	D15: DL06	I-1S: DL09	I-2S: DL11	I-3S: DL13	I-4S: DL15	I-5S: DL16	O2: DL20	O3: DL22	O4: DL24	O5: DL25	O7: DL28	TW1: DL04
1997	1														
	2														
	3														
	4			1.1											
1998	1														
	2														
	3														
	4														
1999	1														0.34
	2														
	3														
	4														
2000	1														
	2														
	3														
	4														
2001	1											3.3			
	2														
	3														
	4														
2002	1														
	2														
	3														
	4														
2003	1														
	2														
	3														
	4														
2004	1														
	2														
	3														
	4														
Key		Analysis was performed, but Pu-239/240 was not detected.													
		Pu-239/240 was detected (pCi/L).													
		If more than one positive detection occurred in a single quarter, then only the highest concentration is listed.													
		Note: 1E-05 RBC = 3.53 pCi/L FY = fiscal year RBC = risk-based concentration													

Figure 3-36. Occurrences of plutonium-239/240 detections in intermediate-depth lysimeters since Fiscal Year 1997.

Plutonium-238																							
Radioactive Waste Management Complex Perched Water and Lysimeters (>140 ft)																							
FY	Qtr	8802D	DE4: DL33	DE7: DL36	DE7: DL37	D10	I2D: DL10	I3D: DL12	I4D: DL14	IE3: DL30	IE4: DL32	IE6: DL34	IE7: DL35	IE8: DL38	O2: DL19	O3: DL21	O4: DL23	O6: DL26	O7: DL27	O8: DL29	S1898: DL40	TW1: DL03	USGS- 092
1997	1																						
	2																						
	3																						
	4																						
1998	1																						
	2																						
	3																						
	4																						
1999	1																						
	2																						
	3																						
	4																						
2000	1																						
	2																						
	3																						
	4																						
2001	1																						
	2																						
	3																						
	4																						
2002	1																						
	2																						
	3																						
	4																						
2003	1																						
	2																						
	3																						
	4																						
2004	1																						
	2																						
	3																						
	4																						
Key		Analysis was performed for Pu-238, but none was detected.																					
		Pu-238 was detected (pCi/L).																					
		If more than one positive detection occurred in a well in a single quarter, only the highest concentration is listed.																					
		Note: 1E-05 RBC = 3.64 pCi/L																					
		FY = fiscal year																					
		RBC = risk-based concentration																					

Figure 3-37. Occurrences of plutonium-238 detections in deep lysimeters since Fiscal Year 1997.

Plutonium-239/240 Radioactive Waste Management Complex Perched Water and Lysimeters (>140 ft)																							
FY	Qtr	8802D	DE4: DL33	DE7: DL36	DE7: DL37	D10	I2D: DL10	I3D: DL12	I4D: DL14	IE3: DL30	IE4: DL32	IE6: DL34	IE7: DL35	IE8: DL38	O2: DL19	O3: DL21	O4: DL23	O6: DL26	O7: DL27	O8: DL29	S1898: DL40	TW1: DL03	USGS- 092
1997	1																						
	2																						
	3																						
	4																						
1998	1																						
	2																						
	3																						
	4																						
1999	1																						
	2																						
	3																						
	4																						
2000	1																						
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2001	1																						
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2002	1																						
	2																						
	3																						
	4																						
2003	1																						
	2																						
	3																						
	4																						
2004	1																						
	2																						
	3																						
	4																						
Key		Analysis was performed for Pu-239/240, but none was detected.																					
		Pu-239/240 was detected (pCi/L).																					
		If more than one positive detection occurred in a well in a single quarter, only the highest concentration is listed.																					
		Note: 1E-05 RBC = 3.53 pCi/L MCL = 15 pCi/L (total alpha) RBC = risk-based concentration																					

Figure 3-38. Occurrences of plutonium-239/240 detections in deep lysimeters since Fiscal Year 1997.

		Plutonium-238 Radioactive Waste Management Complex Aquifer-Monitoring Wells															
FY	Qtr	A11A31	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	M1S	M3S	M4D	M6S	M7S	OW-2	USGS-127
1997	1																
	2																
	3																
	4																
1998	1																
	2																
	3																
	4																
1999	1																
	2																
	3												0.044				
	4																
2000	1																
	2																
	3																
	4										0.37						
2001	1		0.018	0.030							0.019		0.028		0.071		
	2		OOS											0.17			
	3		OOS														
	4		OOS						0.034								
2002	1		OOS														
	2		OOS														
	3		OOS														
	4		OOS														
2003	1		OOS														
	2		OOS														
	3		OOS														
	4		OOS														
2004	1		OOS														
	2		OOS														
	3	.047	OOS										.102				
Key		Analysis was performed, but Pu-238 was not detected.															
		Pu-238 was detected (pCi/L).															
		If more than one positive detection occurred in a single quarter, then only the highest concentration is listed. Note: MCL = 15 pCi/L total alpha FY = fiscal year MCL = maximum contaminant level OOS = out of service. Well rendered inoperable after attempts at repairs were unsuccessful															

Figure 3-39. Occurrences of plutonium-238 detections in aquifer samples collected around the Radioactive Waste Management Complex since Fiscal Year 1997.



		Plutonium-239/240 Radioactive Waste Management Complex Aquifer-Monitoring Wells															
FY	Qtr	A11 A31	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	M1S	M3S	M4D	M6S	M7S	OW-2	USGS-127
1997	1																
	2																
	3																
	4																
1998	1																
	2																
	3																
	4																
1999	1																
	2																
	3																
	4																
2000	1																
	2																
	3																
	4																
2001	1																
	2																
	3																
	4																
2002	1																
	2																
	3																
	4																
2003	1																
	2																
	3																
	4																
2004	1																
	2																
	3																
Key		Analysis was performed, but Pu-239/240 was not detected.															
		Pu -239/240 was detected (pCi/L).															
		If more than one positive detection occurred in a single quarter, then only the highest concentration is listed.															
		Note: MCL = 15 pCi/L total alpha FY = fiscal year MCL = maximum contaminant level OOS = out of service. Well rendered inoperable after attempts at repairs were unsuccessful.															

Figure 3-40. Occurrences of plutonium-239/240 detections in aquifer samples collected around the Radioactive Waste Management Complex since Fiscal Year 1997.

Table 3-35. Plutonium detected above aquifer background concentrations.

Radionuclide	Sample Date	Well	Sample Result $\pm 1\sigma$ (pCi/L)	Reanalysis Result $\pm 1\sigma$ (pCi/L)	MDC (pCi/L)	Aquifer Background <sup>a</sup> (pCi/L)	MCL <sup>b</sup> (pCi/L)
Pu-238	04/26/04	A11A31	<b>0.047 <math>\pm</math> 0.011<sup>c</sup></b>	0.000 $\pm$ 0.009 <sup>d</sup>	0.027	0.0	15
Pu-238	04/29/04	M4D	<b>0.102 <math>\pm</math> 0.016<sup>c</sup></b>	-0.000 $\pm$ 0.009 <sup>d</sup>	0.006	0.0	15

a. The USGS established the SRPA background ranges in 1992 from samples collected upgradient (i.e., Mud Lake area) and downgradient (i.e., Magic Valley area) of the INL (Knobel, Orr, and Cecil 1992).

b. The MCLs are from the "National Primary Drinking Water Regulations" (40 CFR 141) established by the EPA.

c. **Black bold font** indicates sample concentrations less than the MCL, but exceeding aquifer background concentrations (see Footnote a).

d. The sample was reanalyzed and plutonium-238 was not detected.

EPA = U.S. Environmental Protection Agency

INL = Idaho National Laboratory

MCL = maximum contaminant level

MDC = minimum detectable concentration

SRPA = Snake River Plain Aquifer

USGS = United States Geological Survey

### 3.8.4 Summary of Plutonium

Plutonium-238 and Pu-239/240 were not detected in the vadose zone soil-moisture samples or perched water samples in FY 2004. There were two unconfirmed and highly questionable detections of Pu-238 in Aquifer Wells A11A31 and M4D, and Pu-238 was detected in one of three soil samples collected while drilling Lysimeter Well RWMC-2005. Because there is a possibility that low-level Pu-238 detections can be false positive, due to potential interferences from natural radioactivity, no action other than continued monitoring is warranted. Locations of historical Pu-238 and Pu-239/240 detections in the vadose zone are depicted in Figure 3-41a and 3-41b, respectively, with the density (curies of plutonium per square foot) of plutonium-containing disposals. Plutonium detections are sporadic and do not point to any discernable trends.

Plutonium-239/240 has not been detected more than once at any SDA lysimeter, perched water, or aquifer well location since monitoring began in FY 1997. Figure 3-42 presents a time history of vadose zone and aquifer plutonium concentrations since 1997. Plutonium-238 was detected more than once in Lysimeters PA01 and PA03 (see Figure 41a) and in Aquifer Well M6S (see Figure 3-42). Both lysimeter wells are located near Pad A. Lysimeter PA01 is 4.3 m (14 ft) deep and is located north of known disposals in Pits 4 and 6. Lysimeter PA03 is 3 m (10 ft) deep and is located just north of Pad A, with no known plutonium disposals nearby. Plutonium has not been detected in Lysimeter PA03 from FY 1998 until the lysimeter was damaged in FY 2000. The lysimeter was repaired in late 2003, and samples will be collected the next time soil moisture is available. Aquifer Well M6S is located approximately 0.4 km (0.25 mi) southeast of the RWMC. Plutonium has not been detected in this aquifer well since 2001.

In soil-moisture and perched water samples from 1997, nine of the 16 detections were from the Pit 5 and Pad A areas (i.e., Wells PA01, PA02, PA03, D06, and TW1), three of the 16 occurred in the western part of the SDA (i.e., Wells 98-4, 98-5, and USGS-92), and four of the 16 occurred in the western part of the RWMC, but outside the SDA (i.e., Wells D15, O4S, and O6D).

Contrary to expectations based on an order-of-magnitude larger burial of Pu-239/240 compared to Pu-238, most subsurface plutonium detections are Pu-238 rather than Pu-239/240. Of the 16 plutonium detections in the vadose zone since FY 1997, 11 (69 percent) were Pu-238. In the SRPA, 87 percent (13 out of 15) of the plutonium detections since FY 1997 were Pu-238. Plutonium-238 is associated with nuclear fuel rather than RFP weapons-related waste. In contrast, most of the plutonium-containing disposals are documented as originating from RFP, which would contain proportionately more Pu-239/240. A study by Kubilius et al. (2004) determined low-level Pu-238 detections analyzed at commercial laboratories can be false positive. False positive results can occur when incomplete chemical separations include interfering radionuclides.

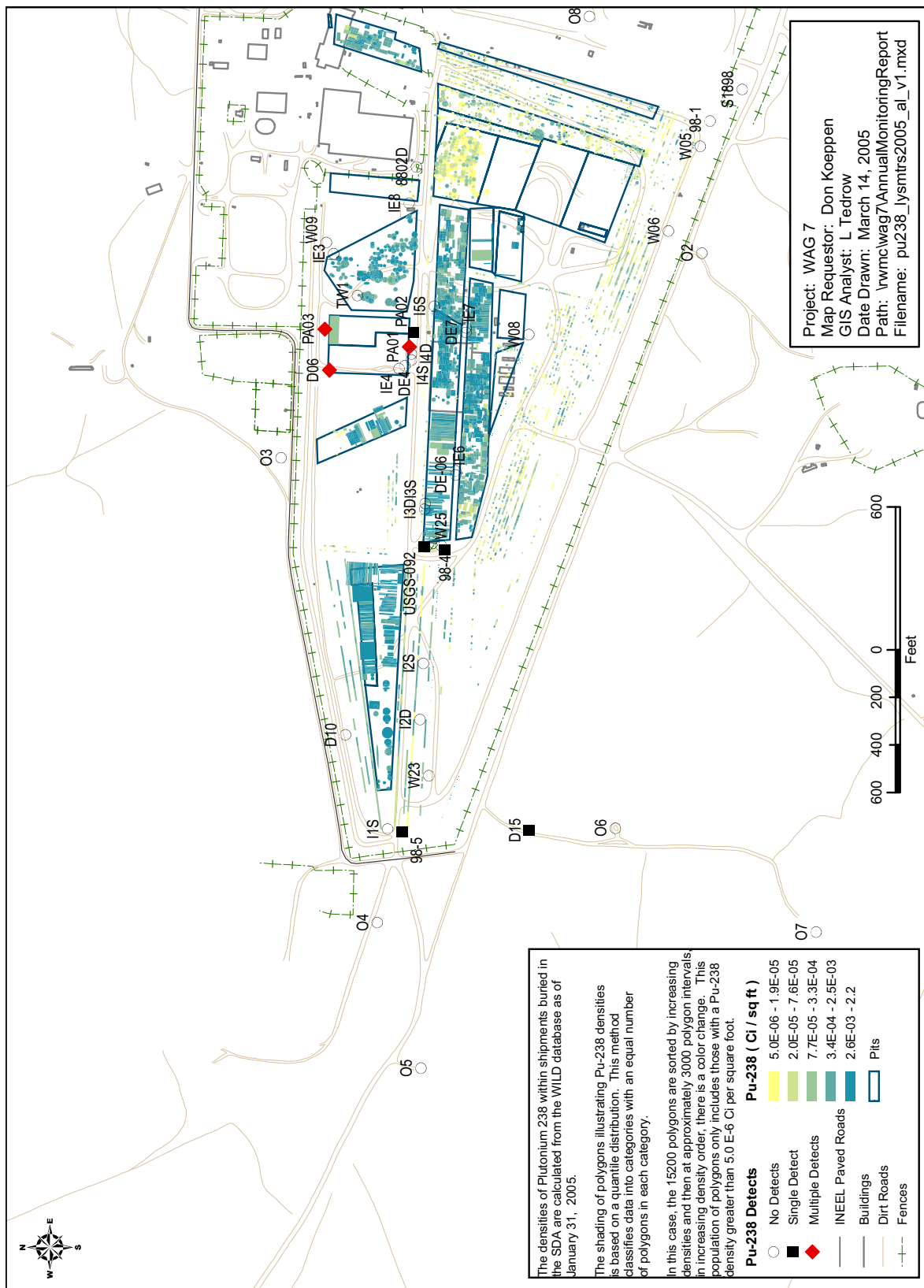
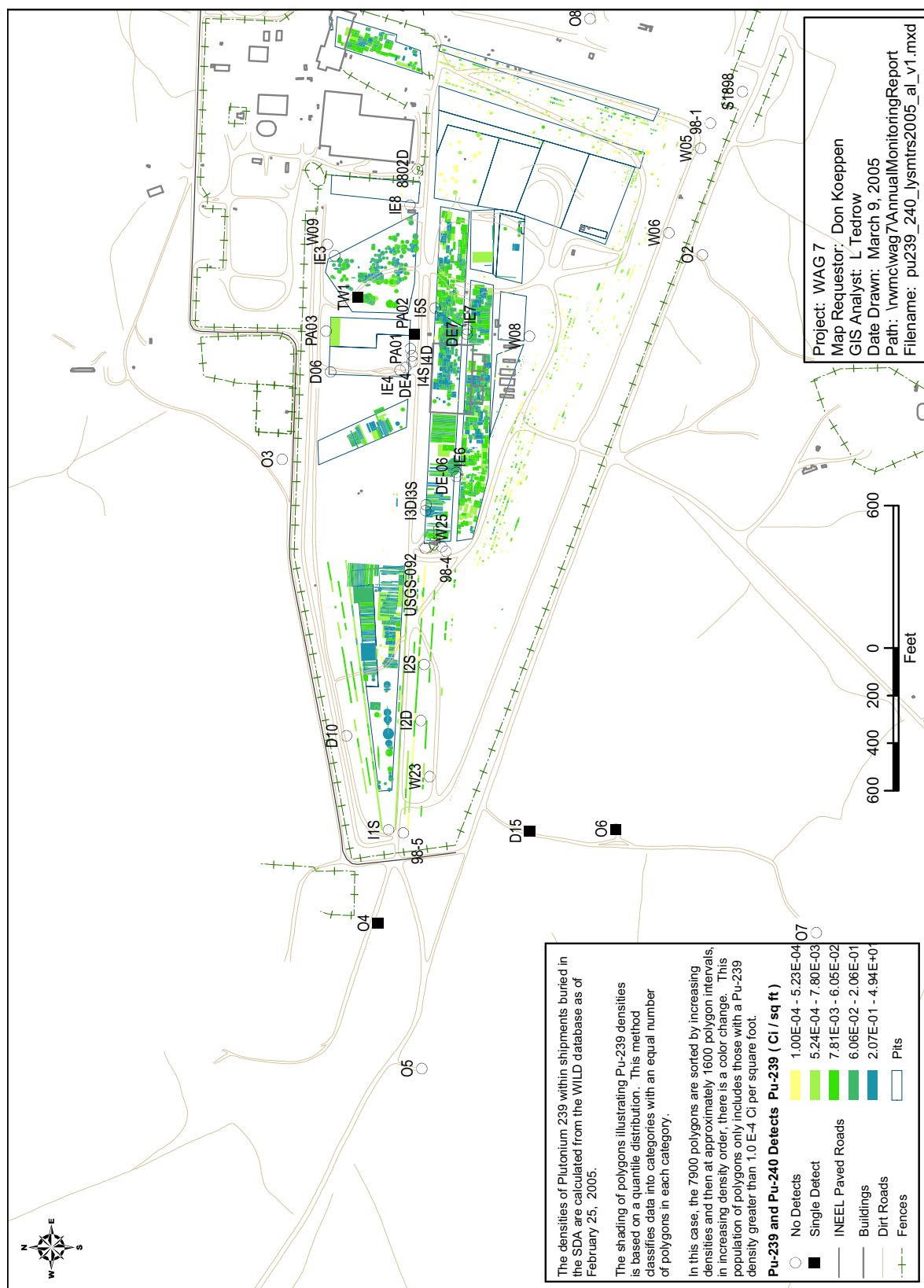


Figure 3-41a. Plutonium-238 disposal locations and vadose zone detection locations at the Subsurface Disposal Area.



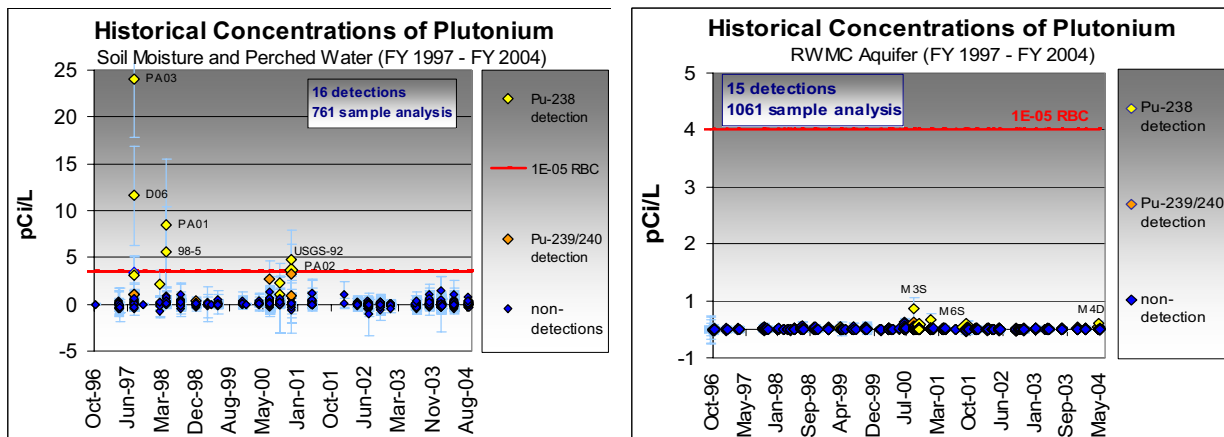


Figure 3-42. Plutonium concentration time history associated with Subsurface Disposal Area vadose zone and Radioactive Waste Management Complex aquifer monitoring for Fiscal Year 2004.

Many of the positive detections of just Pu-238 (characteristic of reactor operations waste) were associated with monitoring wells around Pad A (i.e., Wells PA01, PA02, PA03, and D06), yet there is also a concentration of monitoring wells in this area. Plutonium-238 sorbs strongly to sediments under most environmental conditions; if it moves, it is likely to be moving in a colloidal form, which may be difficult to collect or intercept with a lysimeter, because colloids may be mechanically filtered or strained by the porous lysimeter cup. Buried reactor operations waste containing Pu-238 would also contain uranium, which is more mobile. If the objective is to identify whether Pu-238 is moving in the vadose zone, it is likely that trends in the more mobile uranium would be detected prior to Pu-238 trends. Occurrence of a surrogate or co-occurring contaminant could be used as justification for further Pu-238 investigation. Low-level detections of just Pu-239/240 (characteristic of weapons manufacturing waste) were associated with soil-moisture samples from monitoring wells in Pit 5 (i.e., Well TW1) and outside the SDA (i.e., Wells D15, O4, and O6). Sample results from Wells D15 and PA02 had detections of both Pu-238 and Pu-239/240. The isotopic ratio of Well D15 results was inconclusive, whereas that of Well PA02 suggests plutonium from reactor operations waste.

### 3.9 Radium-226

Radium-226 is a radioactive decay product in the naturally occurring U-238 decay chain and in the Pu-238 decay chain. Inventories were updated and predicted risk estimates recalculated in FY 2004. The risk from Ra-226 changed and is no longer considered a COC for OU 7-13/14. Although Ra-226 has been a targeted analyte in the past, it was removed from the target analyte list. Results from the standard gamma analysis of Ra-226 are confounded by interferences from other radionuclides. At the same time, Ra-226 continues to be a concern for the PA and PC, and has an action level in the aquifer. Aquifer samples are gamma scanned; and should Ra-226 be detected, the laboratory is committed to reporting the positive detections. No quantities of Ra-226 were reported in FY 2003 or 2004.

### 3.10 Strontium-90

Strontium-90 is generated by nuclear reactor operations. Approximately  $1.36 \times 10^5$  Ci of Sr-90 was buried in the SDA, mostly from INL reactor operations and subassembly hardware. Carcinogenic risk of Sr-90 is primarily through a surface exposure pathway (e.g., crop ingestion). Strontium-90 is of concern to the PA and PC and has an action level in the aquifer.

### 3.10.1 Waste Zone

Waste zone soil-moisture samples are not analyzed for Sr-90.

### 3.10.2 Vadose Zone

#### 3.10.2.1 Subsurface Soil Samples Collected While Drilling Lysimeter Well RWMC-2005.

In April 2004, while drilling Lysimeter Well RWMC-2005 in the east end of the SDA (see Figure 2-3), radioactivity above background was detected in the drilling returns. Drilling was stopped, and three separate soil samples were collected from these returns. The samples were analyzed for radionuclides, and Sr-90 was detected in all three samples (see Table 3-36).

Table 3-36. Strontium-90 detections in Fiscal Year 2004 Subsurface Disposal Area vadose zone soil sample.

Radionuclide	Sample Date	Well: Lysimeter	Lysimeter Depth (ft)	Sample Result $\pm 1\sigma$ (pCi/g)	MDC (pCi/g)	INL Soil Background UTL <sup>a</sup> (pCi/g)	Soil RBC <sup>b</sup> (pCi/g)
Sr-90	04/26/04	RWMC-2005	8.9	<b>2.71 <math>\pm</math> 0.16<sup>c</sup></b>	0.5	0.76	55.1
Sr-90	04/26/04	RWMC-2005	8.9	<b>3.9 <math>\pm</math> 0.2<sup>c</sup></b>	0.4	0.76	55.1
Sr-90	04/26/04	RWMC-2005	8.9	<b>59.0 <math>\pm</math> 1.1<sup>d,e</sup></b>	0.4	0.76	55.1

a. INL surficial soil background 95% upper tolerance concentration limits for grab samples are not directly applicable to subsurface soils, but are provided here only as a basis for comparison. The surficial soil background tolerance limits were established in 1996 (Rood, Harris, and White 1996).

b. Calculated RBC for soil is equivalent to an increased cancer risk of 1E-05.

c. **Black bold font** indicates sample concentrations less than the RBC, but exceeding surficial soil background upper tolerance limit (see Footnote a).

d. **Red bold font** indicates sample concentrations that exceed the 1E-05 RBC (see Footnote b).

e. The laboratory performed duplicate analyses in accordance with routine internal quality control protocol. The duplicate analysis result for Sr-90 was 60.8  $\pm$  1.2 pCi/g. Laboratory internal quality control test results, not normally reported in these summary tables, are included to provide additional evidence of the presence of Sr-90 at this location.

MDC = minimum detectable concentration

RBC = risk-based concentration

UTL = upper 95% tolerance level with 95% confidence

**3.10.2.2 Lysimeter Samples at Depths of 0 to Greater than 140 ft.** No soil-moisture or perched water samples from the vadose zone were analyzed for Sr-90 in FY 2004, because Sr-90 is not a priority contaminant for OU 7-13/14. The PA and CA do not have an action level for Sr-90 in the vadose zone. Historical detections of Sr-90 in shallow lysimeters are shown in Figure 3-43. One detection of Sr-90 occurred in the intermediate-depth lysimeters, and no detections have occurred in the deep vadose zone since monitoring for it began in 1997; therefore, figures showing occurrences at the deeper depths are not presented. The Sr-90 detection of 4.1  $\pm$  1.2 pCi/L occurred in the TW1-DL04 intermediate-depth lysimeter in November 1998.

### 3.10.3 Aquifer

Fifty aquifer samples were collected from 15 RWMC monitoring wells and screened for Sr-90 activity in FY 2004 using gross beta analysis. Fifteen sample results exceeded the gross beta trigger level of 5 pCi/L and were analyzed for Sr-90, with no positive detections. The trigger level of 5 pCi/L is set below the MCL of 8 pCi/L. No Sr-90 has been detected in RWMC aquifer samples since monitoring began in FY 1997; therefore, a figure showing occurrences is not presented.

Strontium-90 Radioactive Waste Management Complex Lysimeters (0–35 ft)																	
FY	Qtr	98-1: L35	98-4: L38	98-5: L39	D15: DL07	PA01: L15	PA02: L16	PA03: L33	W05: L25	W06: L27	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
1997	1																
	2																
	3																
	4																
1998	1																
	2																
	3																
	4																
1999	1																
	2																
	3																
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2000	1																
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2001	1																
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	3																
	4																
2002	1																
	2																
	3																
	4																
2003	1																
	2																
	3																
	4																
2004	1																
	2																
	3																
	4																
Key		Analysis was performed, but Sr-90 was not detected.															
		Sr-90 was detected (pCi/L).															
		If more than one positive detection occurred in a single quarter, then only the highest concentration is listed.															
		MCL = 8 pCi/L															
		FY = fiscal year															
		MCL = maximum contaminant level															

Figure 3-43. Occurrences of strontium-90 in shallow lysimeter samples since Fiscal Year 1997.



The gross beta activities measured in all aquifer-monitoring wells around the RWMC were typical of concentrations normally found in the aquifer, with the exception of Well M4D. Well M4D gross beta activity has been consistently higher than gross beta levels observed in all other monitoring wells at the RWMC and has remained relatively constant throughout the past 11-year monitoring period. The gross beta activity for Well M4D is consistently around 22 pCi/L, whereas all other RWMC monitoring wells are about 4 pCi/L. Because Well M4D is much deeper than other RWMC aquifer-monitoring wells (i.e., 244 versus approximately 198 m [838 versus approximately 650 ft]), and because elemental potassium is appreciably above SRPA background levels in this well, the higher gross beta activity likely is due to elevated levels of natural K-40. The concentration difference of other geochemical and radiochemical constituents (i.e., calcium, sodium, magnesium, and natural uranium) between Well M4D and the other RWMC wells suggests that M4D is located in a section of the aquifer that is isolated from the shallower wells.

### 3.10.4 Summary of Strontium-90

No Sr-90 was detected in RWMC aquifer samples in FY 2004. Historical detections of Sr-90 in the vadose zone are shown in Figure 3-44 along with known disposal locations. Lysimeter 98-IL35, the only lysimeter where Sr-90 has been detected more than once, is located at the southeast corner of the SDA. The Sr-90 detections are sporadic and not indicative of emerging trends.

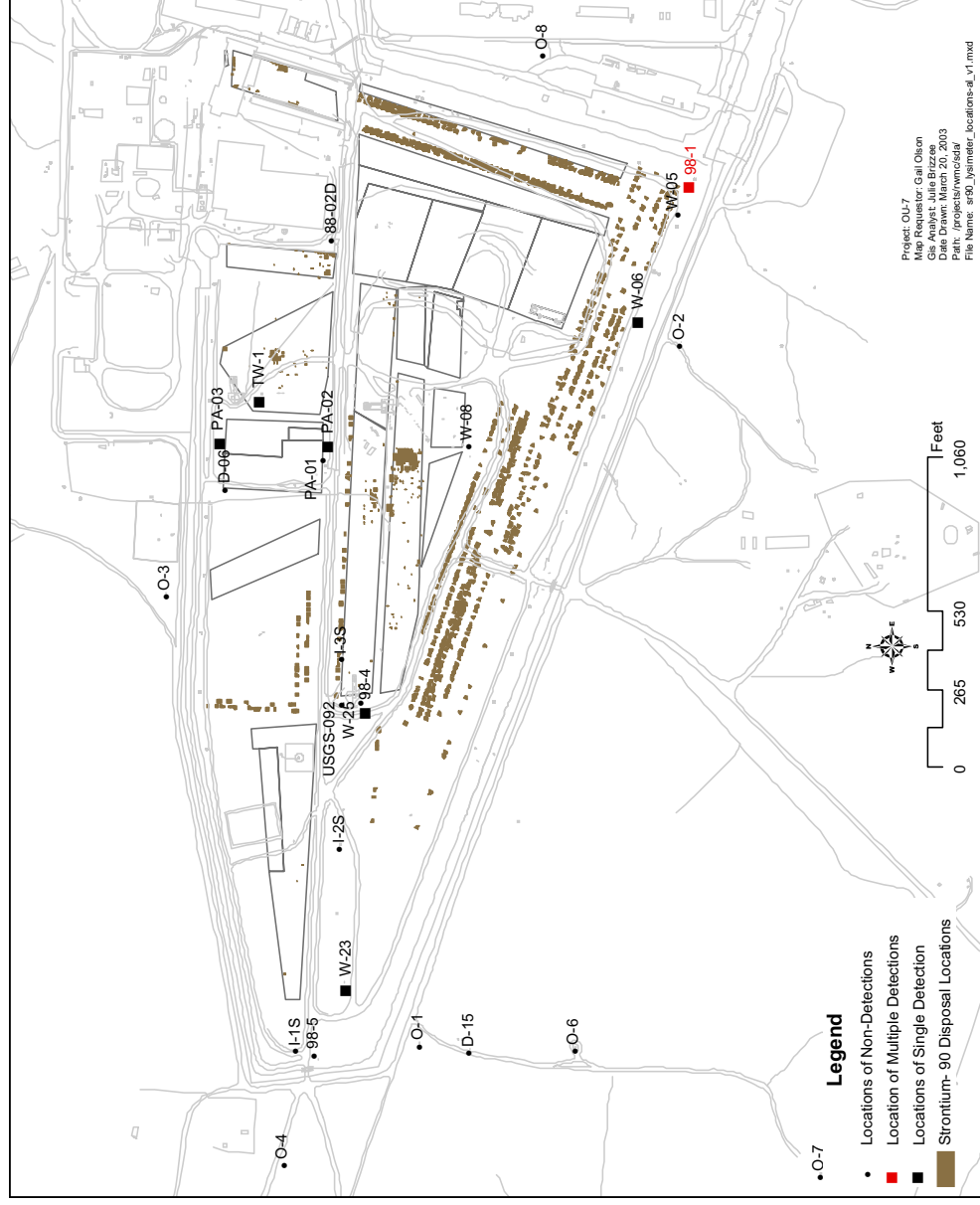


Figure 3-44. Strontium-90 disposal locations and vadose zone detection locations at the Subsurface Disposal Area.



### 3.11 Technetium-99

Technetium-99 is a fission product generated primarily by nuclear reactor operations. Approximately 40 Ci of Tc-99 was buried in the SDA, according to inventory estimates through 1999. Most originated from INL reactor operations waste. It is a beta and low-energy gamma emitter. It has a half-life of  $2.13 \times 10^5$  years. Technetium is a very mobile contaminant that has been detected in vadose zone cores, lysimeters, perched water, and aquifer samples. Historical core sampling in the SDA detected Tc-99 inside the SDA boundary, but not in cores outside the boundary. Detection rates in the vadose zone have been relatively constant with depth, while aquifer detection rates are much lower (Holdren et al. 2002). Waste Zone

Eighteen waste zone lysimeters were sampled every quarter in FY 2004, and Lysimeters 741-08-L1 and 743-18-L2, located in Pits 10 and 4, respectively, were the only waste zone lysimeters to yield samples. Unfortunately, the volumes obtained were very small, permitting analysis for plutonium isotopes, uranium isotopes, Am-241 and gamma-emitting radionuclides, but not sufficient for Tc-99 analysis.

#### 3.11.1 Vadose Zone

##### 3.11.1.1 Subsurface Soil Samples Collected While Drilling Lysimeter Well RWMC-2005.

In April 2004, while drilling lysimeter well RWMC-2005 in the east end of the SDA (see Figure 2-3), radioactivity above background was detected in the drilling soil returns. Drilling was stopped, and three separate soil samples were collected from these returns. The samples were analyzed for radionuclides, and Tc-99 was detected in all three samples (see Table 3-37).

Table 3-37. Technetium-99 detections in Fiscal Year 2004 Subsurface Disposal Area vadose zone soil sample.

Radionuclide	Sample Date	Well: Lysimeter	Lysimeter Depth (ft)	Sample Result $\pm 1\sigma$ (pCi/g)	MDC (pCi/g)	INL Soil Background UTL <sup>a</sup> (pCi/g)	Soil RBC <sup>b</sup> (pCi/g)
Tc-99	04/26/04	RWMC-2005	8.9	<b><math>3.7 \pm 0.2</math></b> <sub>J</sub> <sup>c</sup>	0.8	NE	1,036
Tc-99	04/26/04	RWMC-2005	8.9	<b><math>2.19 \pm 0.12</math></b> <sub>J</sub> <sup>c</sup>	0.8	NE	1,036
Tc-99	04/26/04	RWMC-2005	8.9	<b><math>33.4 \pm 1.7</math></b> <sub>J</sub> <sup>cd</sup>	1.2	NE	1,036

a. INL surficial soil background 95% upper tolerance concentration limits for grab samples are not directly applicable to subsurface soils, but are provided here only as a basis for comparison. The surficial soil background tolerance limits were established in 1996 (Rood, Harris, and White 1996).

b. Calculated RBC for soil is equivalent to an increased cancer of  $1 \times 10^{-5}$ .

c. **Black bold font** indicates sample concentrations less than the RBC, but exceeding surficial soil background upper tolerance limit (see Footnote a). The "J" flags were assigned to the Tc-99 results because of low analytical tracer yields and/or duplicate imprecision. The results are usable, but should only be used as estimated quantities.

d. The laboratory performed duplicate analyses in accordance with routine internal quality control protocol. The duplicate analysis result for Tc-99 was  $11.5 \pm 0.6$  pCi/g. Laboratory internal quality control test results, not normally reported in these summary tables, are included to provide additional evidence of the presence of Tc-99 at this lysimeter location.

INL = Idaho National Laboratory

MDC = minimum detectable concentration

RBC = risk-based concentration

UTL = upper 95% tolerance level with 95% confidence

**3.11.1.2 Lysimeter Samples at Depths of 0–35 ft.** Twenty-three Tc-99 analyses were performed on soil-moisture samples collected from nine shallow lysimeters in and around the SDA in FY 2004, with two positive detections (see Table 3-38). The detected concentrations were below the  $1 \times 10^{-5}$  RBC for the aquifer. Most historical detections in the 0–11-m (0–35-ft) region of vadose zone are from lysimeter wells located around Pad A (i.e., Wells PA01 and PA03) and the western part of the SDA (i.e., Wells 98-5 and W23). Historical detections of Tc-99 in the shallow vadose zone are shown in Figure 3-45.

Table 3-38. Technetium-99 detections in FY 2004 Subsurface Disposal Area vadose zone soil-moisture samples from the 0–35-ft depth interval.

Radionuclide	Sample Date	Well: Lysimeter	Lysimeter Depth (ft)	Sample Result $\pm 1\sigma$ (pCi/L)	MDC (pCi/L)	Local Soil-Moisture Background <sup>a</sup> (pCi/L)	RBC <sup>b</sup> (pCi/L)
Tc-99	10/27/03	98-5:L39	10.5	<b>19 <math>\pm 5^c</math></b>	16	0.0	173
Tc-99	05/04/04	W23:L09	7.7	<b>35 <math>\pm 9^c</math></b>	30	0.0	173

a. The local soil moisture background concentration for technetium-99 is essentially zero and defined as a nondetect (i.e., a result less than or equal to its MDC and less than or equal to three times its reported  $1\sigma$  uncertainty). Local soil-moisture background concentrations are established with lysimeter samples regularly collected from the “O” and D15-series lysimeter wells located outside of the SDA.

b. RBC =  $1\text{E-}05$  for drinking water. The RBCs for the aquifer are provided here as a basis of comparison.

c. **Black bold font** indicates sample concentrations less than the RBC, but exceeding local soil-moisture background concentrations (see Footnote a). Concentration values with a “J” subscript denote that “J” data validation qualifier flags were assigned. The “J” flag was assigned to the Tc-99 result because of duplicate imprecision. The results are questionable but usable, but should only be used as estimated quantities.

MDC = minimum detectable concentration

RBC = risk-based concentration

SDA = Subsurface Disposal Area

**3.11.1.3 Lysimeter Samples at Depths of 35–140 ft.** Forty-two Tc-99 analyses were performed on soil-moisture samples collected from 16 intermediate-depth lysimeters in and around the SDA in FY 2004, with six positive detections (see Table 3-39). Technetium-99 concentrations in Lysimeters D06:DL02 and O7:DL28 exhibited a sudden increase that exceeded the RBC. Such an increase in Well O7 is unexpected and questionable because the well is about 0.4 km (0.25-mi) southwest of the SDA, and water from the SDA usually flows to the east–southeast, because the interbeds generally slope in that direction. Also, the well has no history of consistent detections, and subsequent samples collected from this well had no positive Tc-99 detections. Monitoring of this distant lysimeter well for Tc-99 will continue. Lysimeter D06:DL02, located at 13 m (44 ft) bls, had one detection since 1997; however, the lysimeter located at 10 m (88 ft) bls (D06:DL01) has consistent Tc-99 detections with a concentration trend developing (see Figure 3-46). Most historical detections in the 11–43-m (35–140-ft) region of the vadose zone are from lysimeter wells located around Pad A (i.e., Lysimeter D06) and the western part of the SDA (i.e., Lysimeters IIS and D15). Historical detections in lysimeter samples from this depth range are depicted in Figure 3-47.

Table 3-39. Technetium-99 detections in FY 2004 Subsurface Disposal Area vadose zone soil-moisture samples from the 35–140-ft depth interval.

Radionuclide	Sample Date	Well: Lysimeter	Lysimeter Depth (ft)	Sample Result $\pm 1\sigma$ (pCi/L)	MDC (pCi/L)	Local Soil-Moisture Background <sup>a</sup> (pCi/L)	RBC <sup>b</sup> (pCi/L)
Tc-99	10/28/03	D06:DL01	88	<b>40 <math>\pm 4^c</math></b>	13	0.0	173
Tc-99	10/27/03	I-1S:DL09	101	<b>32 <math>\pm 5^c</math></b>	16	0.0	173
Tc-99	10/29/03	O7:DL28	119	<b>1,480 <math>\pm 28^d</math></b>	40	0.0	173
Tc-99	10/27/03	TW1:DL04	101.7	<b>22 <math>\pm 4^c</math></b>	14	0.0	173
Tc-99	05/03/04	D06:DL01	88	<b>90 <math>\pm 5^c</math></b>	15	0.0	173
Tc-99	05/03/04	D06:DL02	44	<b>197 <math>\pm 10^d</math></b>	28	0.0	173

a. The local soil moisture background concentration for technetium-99 is essentially zero and defined as a nondetect (i.e., a result less than or equal to its MDC and less than or equal to three times its reported  $1\sigma$  uncertainty). Local soil-moisture background concentrations are established with lysimeter samples regularly collected from the “O” and D15-series lysimeter wells located outside of the SDA.

b. RBC =  $1\text{E-}05$  for drinking water. The RBCs for the aquifer are provided here as a basis of comparison.

c. **Black bold font** indicates sample concentrations less than the RBC, but exceeding local soil-moisture background concentrations (see Footnote a).

d. **Red bold font** indicates sample concentrations that exceed the RBC (see Footnote b).

MDC = minimum detectable concentration

RBC = risk-based concentration

SDA = Subsurface Disposal Area

Technetium-99 Radioactive Waste Management Complex Lysimeters (0–35 ft)																			
FY	Qtr	98-1: L35	98-4: L38	98-5: L39	D15: DL07	LYS1 : L41	PA01 : L15	PA02 : L16	PA03 : L33	W05: L24	W05: L25	W06: L27	W08: L13	W08: L14	W09: L23	W23: L07	W23: L08	W23: L09	W25: L28
1997	1																		
	2																		
	3																	17	
	4																	30	
1998	1																		
	2																		
	3																		
	4																15*	20	
1999	1																		
	2																		
	3																		
	4																		
2000	1																		
	2																	20	
	3																		
	4																		
2001	1																		
	2																		
	3																		
	4																		
2002	1																		
	2																		
	3																		
	4																	15*	
2003	1																		
	2																		
	3																		
	4																	42	
2004	1																		
	2																		
	3																	35*	
	4																		
Key		Analysis was performed, but Tc-99 was not detected.																	
		Tc-99 was detected (pCi/L.)																	
		If more than one positive detection occurred in a single quarter, then only the highest concentration is listed. * Indicates a positive detection that received a “J” qualifier flag because of a minor quality control anomaly. Note: 1E-05 RBC = 173 pCi/L FY = fiscal year RBC = risk-based concentration																	

Figure 3-45. Occurrences of technetium-99 detections in shallow lysimeters since Fiscal Year 1997.

Technetium-99 Radioactive Waste Management Complex Lysimeters (35–140 ft)															
FY	Qtr	D06: DL01	D06: DL02	D15: DL06	I-1S: DL09	I-2S: DL11	I-3S: DL13	I-4S: DL15	I-5S: DL16	O2: DL20	O3: DL22	O4: DL24	O5: DL25	O7: DL28	TW1: DL04
1997	1														
	2														
	3														
	4														
1998	1														
	2														
	3														
	4	11	33												
1999	1			43*											20*
	2														
	3														
	4														
2000	1														
	2														
	3			21											
	4														
2001	1														
	2														
	3														
	4														
2002	1														
	2														
	3														
	4														
2003	1	13		28*	29*	25*	18*							20*	
	2														
	3	34													
	4	61													
2004	1	40			32									1480	22
	2														
	3	90	197												
	4														
Key		Analysis was performed, but Tc-99 was not detected.													
		Tc-99 was detected (pCi/L).													
		If more than one positive detection occurred in a single quarter, then only the highest concentration is listed.													
		* Indicates a positive detection that received a “J” qualifier flag because of a minor quality control anomaly.													
		Note: 1E-05 RBC = 173 pCi/L													
		FY = fiscal year													
		RBC = risk-based concentration													

Figure 3-46. Occurrences of technetium-99 detections in intermediate-depth lysimeters since Fiscal Year 1997.

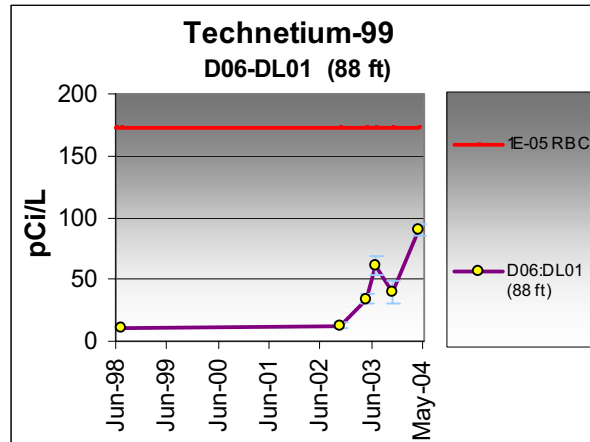


Figure 3-47. Lysimeter D06:DL01 Tc-99 concentration history since monitoring began in 1998.

**3.11.1.4 Lysimeter and Perched Water Samples at Depths Greater than 140 ft.** Fifty-nine Tc-99 analyses were performed on samples collected from 17 lysimeter and three perched water wells in and around the SDA in FY 2004, with three positive detections (see Table 3-40). All detected concentrations were below the 1E-05 RBC for the aquifer. Historical detections in the 43–76-m (140–250-ft) region of the vadose zone are from perched water in the western part of the SDA (USGS-92) and from lysimeter wells located outside the SDA (i.e., Wells O2, O4, O6, and O7). Three unconfirmed detections of Tc-99 have occurred in vadose zone well samples deeper than 43 m (140 ft) since monitoring began in 1997, all from Well USGS-92. Technetium-99 was detected in the filtered sediment portion of two samples since FY 1997 (December 1998 and September 2000). Both detections were less than 4 pCi/L. Technetium also was detected in the liquid portion of the sample at 280 pCi/L (September 2000). Historical detections are shown in Figure 3-48.

Table 3-40. Technetium-99 detections in Fiscal Year 2003 Subsurface Disposal Area vadose zone soil-moisture samples from the 140–250-ft depth interval.

Radionuclide	Sample Date	Well: Lysimeter	Lysimeter Depth (ft)	Sample Result $\pm 1\sigma$ (pCi/L)	MDC (pCi/L)	Local Soil-Moisture Background <sup>a</sup> (pCi/L)	RBC <sup>b</sup> (pCi/L)
Tc-99	10/27/03	IE8:DL38	224	17 $\pm 5^c$	15	0.0	173
Tc-99	10/27/03	DE7:DL37	413	19 $\pm 5^c$	15	0.0	173
Tc-99	05/05/04	IE4:DL32	223	41 $\pm 5^c$	15	0.0	173

a. The local soil moisture background concentration for technetium-99 is essentially zero and defined as a nondetect (i.e., a result less than or equal to its MDC and less than or equal to three times its reported  $1\sigma$  uncertainty). Local soil-moisture background concentrations are established with lysimeter samples regularly collected from the “O” and D15-series lysimeter wells located outside of the SDA.

b. RBC = 1E-05 for drinking water. The RBCs for the aquifer are provided here as a basis of comparison.

c. Black bold font indicates sample concentrations less than the RBC, but exceeding local soil-moisture background concentrations (see Footnote a).

MDC = minimum detectable concentration

RBC = risk-based concentration

SDA = Subsurface Disposal Area

		Technetium-99																					
		Radioactive Waste Management Complex Perched Water and Lysimeters (>140 ft)																					
FY	Qtr	8802D	DE4: DL33	DE7: DL36	DE7: DL37	D10	I2D: DL10	I3D: DL12	I4D: DL14	IE3: DL30	IE4: DL32	IE6: DL34	IE7: DL35	IE8: DL38	O2: DL19	O3: DL21	O4: DL23	O6: DL26	O7: DL27	O8: DL29	S1898: DL40	TW1: DL03	USGS-092
1997	1																						
	2																						
	3																						
	4																						
1998	1																						
	2																						
	3																						
	4																						
1999	1																						28*
	2																						
	3																						
	4																						
2000	1																						
	2																						
	3																						
	4																						280
2001	1																						
	2																						
	3																						
	4																						
2002	1																						
	2																						
	3																						
	4																						
2003	1														31		37	18	29				
	2																						
	3																						
	4																						28
2004	1				19									17									
	2																						
	3										41												
	4																						
Key		Analysis was performed for Tc-99, but none was detected.																					
		Tc-99 was detected (pCi/L).																					
		If more than one positive detection occurred in a well in a single quarter, only the highest concentration is listed.																					
		* Indicates a positive detection that received a "J" qualifier flag because of a minor quality control anomaly.																					
		Note: 1E-05 RBC = 173 pCi/L																					
		RBC = risk-based concentration																					

Figure 3-48. Occurrences of technetium-99 detections in lysimeters deeper than 140 ft since Fiscal Year 1997.

**3.11.1.5 Interbed Cores Samples at Depths from 100–250 ft.** Thirteen Tc-99 analyses were performed on interbed core samples collected from five wells drilled in the SDA during FY 2003, with no positive detections (see locations in Figure 2-6). The FY 2004 interbed core sample results were evaluated to determine whether nondetections are consistent with past detections of Tc-99 in soil moisture and with results from previous core analysis campaigns.

Nondetections in the FY 2004 dataset appeared to be inconsistent with previous core investigations, which concluded that Tc-99 may be present in the B-C and C-D interbeds. Between 1994 and 2000, 52 core samples were collected inside and outside the SDA boundary and analyzed for Tc-99, with 19 positive detections. All detections occurred in core samples collected inside the SDA, and none occurred in cores outside the boundary. The concentration ranges and detection rates in the vicinity of the SDA interbeds are summarized in Table 3-41.

Table 3-41. Summary of previous technetium-99 detections in Subsurface Disposal Area vadose zone core samples from 1994 to 2000 (Holdren et al. 2002)

Interbed	Depth Interval (ft bls)	Concentration Range (pCi/g)	Tc-99 Detection Rate (%)
B-C	98–113	1.08–4.2	36
C-D	223–243	1.46–3.4	63

Results from these interbed core analysis campaigns suggest that the disparate conclusions may be due to the different laboratories used, sample management or handling issues, cross-contamination during sampling, coincidence, moisture conditions at the time of sampling, or a combination of these or other factors.

### 3.11.2 Core Samples

Core samples analyzed by one laboratory consistently reported nondetections while the other laboratory consistently reported detections. The laboratory reporting the nondetections was used in two analysis campaigns, separated by 4 years. Laboratory “G” analyzed all of the FY 2004 core samples and about half of the 1999 and 2000 core samples, with no positive detections. Laboratory “P” analyzed only the 1999 and 2000 core samples from the I-series wells inside the SDA boundary, with 19 detections. Both laboratories used the same analytical methods, achieved similar detection sensitivities, and used comparable analytical quality control test results. The only difference in analytical methodology was laboratory “P” (which detected Tc-99) used a sample mass of about 1 g for analysis; whereas, the laboratory “G” (which did not detect Tc-99) used 6-g aliquots. It is doubtful whether differences in sample mass affected the detectability; because for both labs to have achieved similar detection sensitivities, the lab with the larger sample mass counted the samples for a shorter time interval.

Both sets of data from the laboratory are reliable, defensible, and resolute. Each dataset provides credible evidence in support of a different interpretation. Nondetections were reported for samples that were older than 1 year, but originated from outside of the SDA. Detections were reported from fresh cores originating inside the SDA.

The Tc-99 detections were further evaluated to determine whether they seemed realistic or could be possible. Technetium-99 does not readily adsorb on sediments and does not partition to the solid phase; it remains in the soil water. Using the average bulk density ( $1.5 \text{ g/cm}^3$ ) and moisture content ( $0.3 \text{ cm}^3/\text{cm}^3$ ) of typical vadose zone soils, and the maximum Tc-99 concentration measured in soil-moisture samples ( $280 \text{ pCi/L}$ ) at the SDA, the bulk sediment samples would have a concentration of about  $0.06 \text{ pCi/g}$ . Such a low concentration would not be detected, because it is below the lower limits of detection for the method (less than or equal to  $1 \text{ pCi/g}$ ). The calculated concentrations of Tc-99 in interbed sediments,

based on the highest lysimeter concentration measured at the SDA, suggest that the 1999 and 2000 positive results could be erroneous. Alternatively, positive detections in 1999 and 2000 cannot be ruled out because Tc-99 (1) is known to exist in the SDA, (2) is highly mobile, (3) was detected in all four sediment samples collected from this location in 1999 and 2000, (4) is detected in soil moisture samples obtained from lysimeters in this same area, and (5) is consistent with model predictions.

The different conclusions arising from each dataset also may be due to differences in sample locations (see Figure 3-49) and the possibility that Tc-99 is not widespread throughout the interbeds. However, samples from comparable depths and comparable locations (Well DE4 in FY 2004 and adjacent Well I4D in 2000) yielded contradictory data. In 2000, positive detections of Tc-99 occurred in all four sediment samples collected from Well I4D; whereas, in FY 2004 no detections were observed in the two sediment samples obtained from nearby Well DE4 (see Table 3-42).

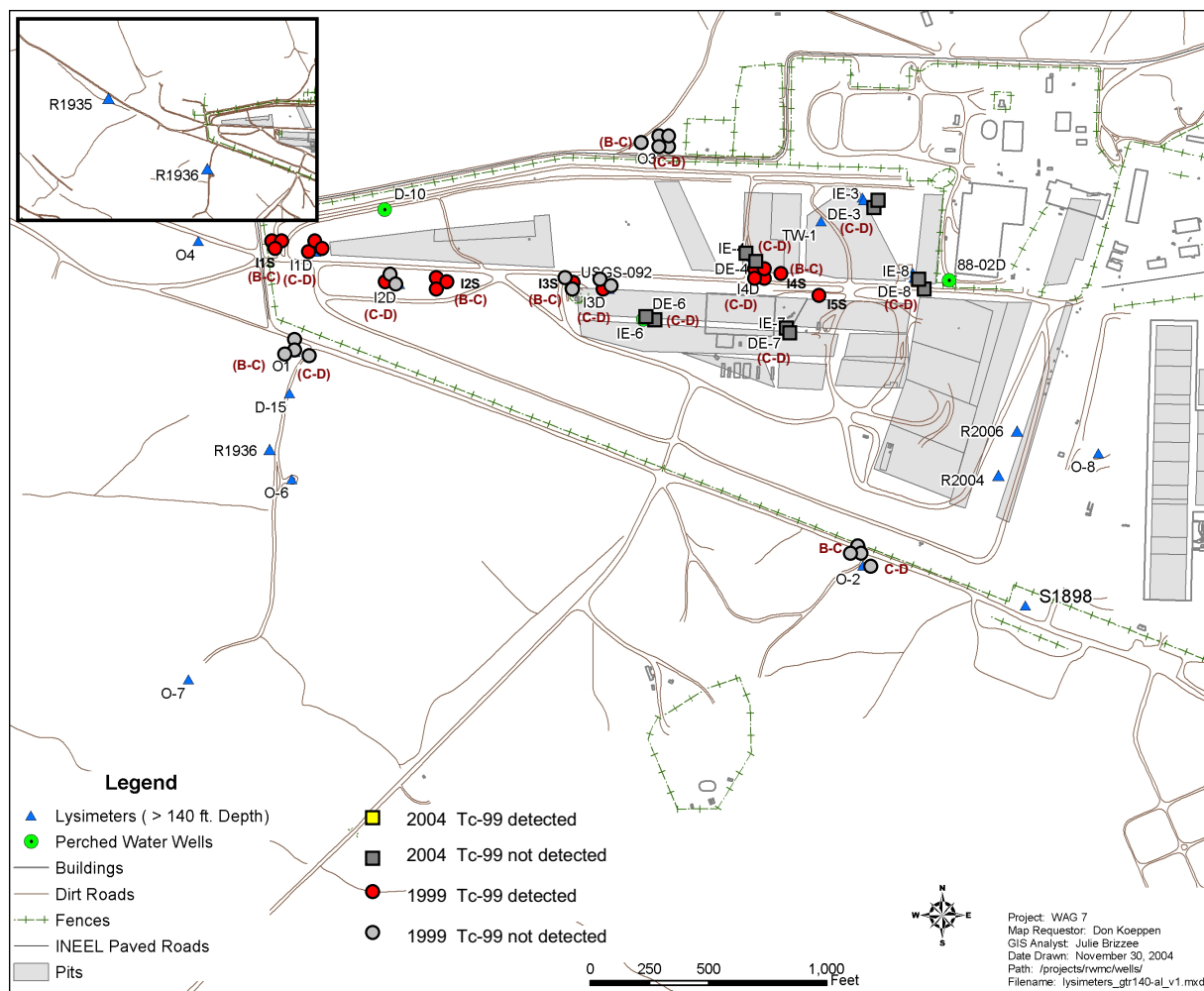




Table 3-42. Comparison of technetium-99 results of interbed sediment samples collected near Pad A in 1999 and 2000 and FY 2004.

Radionuclide	Sample Date	Well:Core	SampleDepth (ft)	Sample Result $\pm 1\sigma$ (pCi/g)	MDC (pCi/g)
Tc-99	01/03/2000	I4D	223.0–223.6	$3.0 \pm 0.4_j^a$	0.7
Tc-99	01/03/2000	I4D	229.6–230.0	$3.1 \pm 0.3_j^a$	0.4
Tc-99	01/05/2000	I4D	237.0–237.5	$3.0 \pm 0.3_j^a$	0.4
Tc-99	01/05/2000	I4D	237.5–238.0	$3.4 \pm 0.3$	0.5
Tc-99	11/24/2003	DE4	232.7–233.2	ND	0.5
Tc-99	11/24/2003	DE4	239.2	ND	0.6

a. Concentration values with a “J” subscript denote that “J” data validation qualifier flags were assigned. The “J” flags were assigned to the Tc-99 results because lab blank results for Tc-99 were statistically positive (i.e.,  $>2\sigma$ , but  $<3\sigma$  and  $<\text{MDC}$ ). Even though the blank results were not true positive detections (i.e., results  $>3\sigma$  and  $>\text{MDC}$ ), other data validation criterion required assignment of “J” flags to the sample results. The results are questionable but usable, and should only be used as estimated quantities.

MDC = minimum detectable concentration

ND = not detected

RBC = risk-based concentration

SDA = Subsurface Disposal Area

A possible resolution to determine the presence or absence of Tc-99 in the SDA interbeds would be to resample the 1999/2000 interbed cores at the precise locations where positive detections of Tc-99 were originally observed, and to have the core material analyzed at the laboratory that reported nondetections.

### 3.11.3 Aquifer

Forty-nine Tc-99 analyses were performed on aquifer samples collected from 15 monitoring wells in the vicinity of the RWMC in FY 2004, with no positive detections. Occurrences of Tc-99 in aquifer samples since FY 1997 are depicted in Figure 3-50.

### 3.11.4 Summary of Technetium-99

Eleven positive detections occurred in the vadose zone and perched water in FY 2004, with concentrations ranging from 17 pCi/L to almost 1500 pCi/L. There were no detections in any of the aquifer samples. Technetium-99 was detected in Lysimeter Well D06 in three out of the five analyses (see Figure 3-50). Since 1997, Perched Water Well USGS-92 and Lysimeter Wells D06, D15, PA01, PA03, W23, and 98-5 have exhibited the most frequent detections (see Figures 3-41, 3-45, 3-46, and 3-48). Most other vadose zone lysimeters have had either one or no detections since monitoring began. Locations of historical Tc-99 detections in the vadose zone are shown on Figure 3-51 along with the density (curies per square foot) of Tc-99. Historically, lysimeter wells with the most frequent and consistent detections of Tc-99 are Wells D06 and W23. A concentration trend appears to be developing in Well D06 (see Figure 3-50). As shown, these wells are located in areas of the SDA where no disposals are noted. The only commonalities between these two wells are that uranium concentrations are elevated, and their isotopic uranium ratios indicate uranium is anthropogenic with a slight U-235 enrichment (see Section 3.10).

None of the 49 aquifer samples collected in FY 2004 contained detectable Tc-99. Detections of Tc-99 occur sporadically in the aquifer (see Figure 3-51) and are not indicative of trends or widespread contamination.

The consistent detections of Tc-99 in D06:DL01 and W23:L09—at depths of 26.8 m (88 ft) and 2.3 m (7.7 ft), respectively—suggest that Tc-99 might be a useful modeling target; however, the inventory records do not indicate that Tc-99 is present in these areas of the SDA. Because the current source release model is based on inventory records, this currently precludes use of this analyte for comparison with modeling results.

Technetium-99 Radioactive Waste Management Complex Aquifer-monitoring Wells																	
FY	Qtr	A11A31	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	M1S	M3S	M4D	M6S	M7S	OW-2	USGS-127
1997	1																
	2																
	3											1.4		1.0			
	4																
1998	1																
	2																
	3																
	4																
1999	1																
	2																
	3																
	4																
2000	1																
	2																
	3									35							
	4																
2001	1																
	2		OOS														
	3		OOS														
	4		OOS														
2002	1		OOS														
	2		OOS												1.2		
	3		OOS														
	4		OOS														
2003	1		OOS														
	2		OOS														
	3		OOS														
	4		OOS														
2004	1		OOS														
	2		OOS														
	3		OOS														
Key		Analysis was performed, but Tc-99 was not detected.															
		Tc-99 was detected (pCi/L).															
		If more than one positive detection occurred in a single quarter, then only the highest concentration is listed.															
		MCL = 900 pCi/L FY = fiscal year MCL = maximum contaminant level OOS = out of service. Well rendered inoperable after attempts at repairs were unsuccessful USGS = United States Geological Survey															

Figure 3-50. Occurrences of technetium-99 in aquifer samples collected in the vicinity of the Radioactive Waste Management Complex since Fiscal Year 1997.

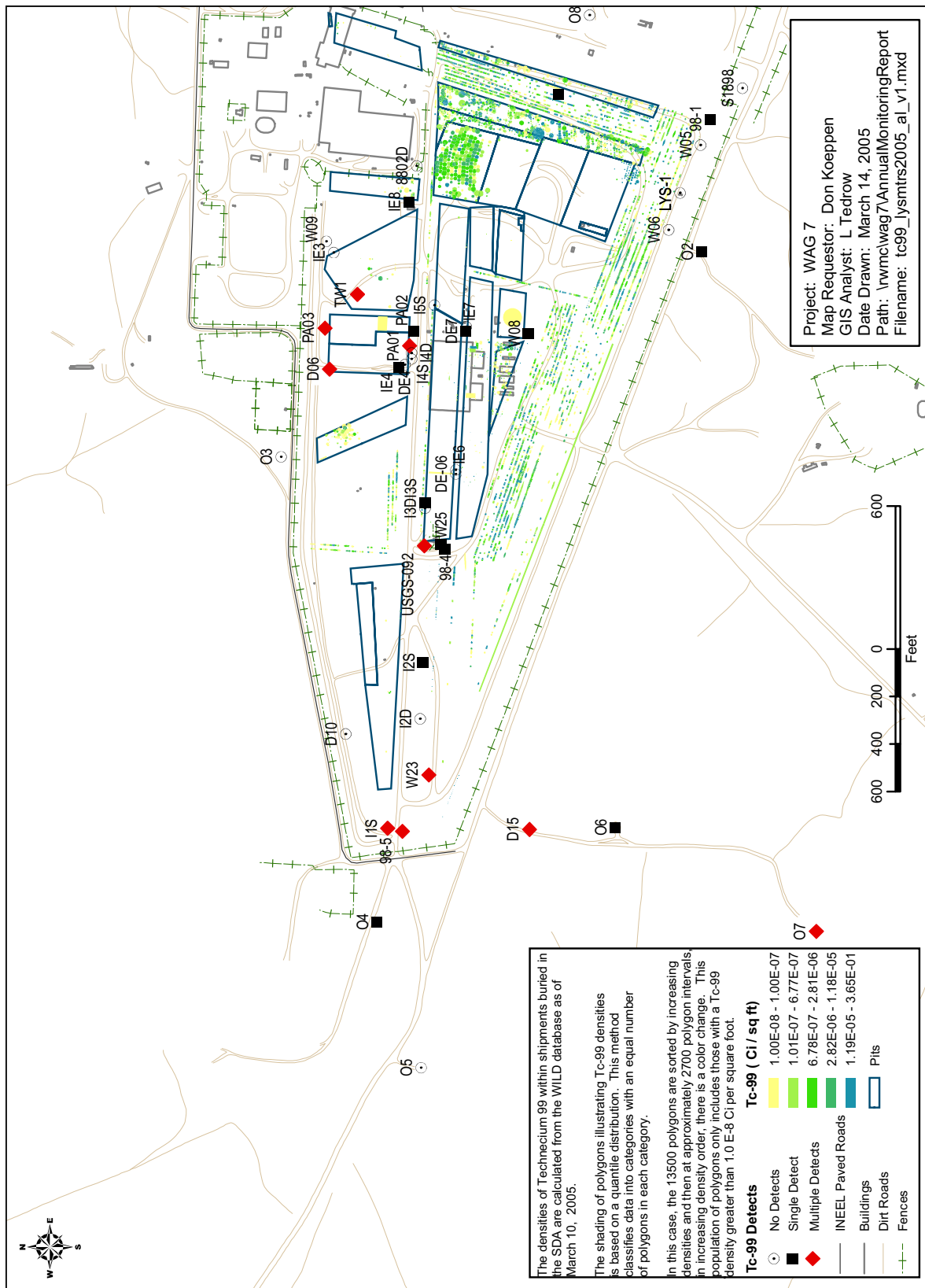


Figure 3-51. Disposals and vadose zone detections of technetium-99 in the Subsurface Disposal Area.

## 3.12 Uranium

Uranium occurs naturally in the environment and is processed and handled for use in nuclear weapons and reactors. Estimated quantities of uranium isotopes buried in the SDA are as follows: 2.1 Ci of U-233, 63.5 Ci of U-234, 4.88 Ci of U-235, 1.43 Ci of U-236, and 141 Ci of U-238, according to inventory estimates through 1999. Because several isotopes are naturally occurring, it is necessary to differentiate background concentrations from anthropogenic uranium. Background concentration guidelines (upper ranges) for U-234 and U-238 in the aquifer beneath the RWMC are 1.9 and 0.9 pCi/L, respectively (Leecaster, Olson, and Koeppen 2003), and the upper background concentration guideline for U-235/236 is 0.15 pCi/L based on the maximum range of 353 U-235/236 results from aquifer samples collected from wells in the vicinity of the RWMC. This upper U-235 concentration range is similar to what has been observed in monitoring wells around the entire INL. Background concentration guidelines for vadose zone soil-moisture samples for U-234, U-235, and U-238 are currently 3.5, 0.7, and 1.8 pCi/L, respectively, based on the mean values plus the standard deviation of the mean of 88 lysimeter samples collected at background locations. The background locations are outside of the SDA fences and are not expected to be impacted by buried waste.

Ratios of uranium isotopes also are expected to remain within a certain range when the uranium is naturally occurring. The U-238:U-235 activity ratio for natural uranium is 21.7. The U-238:U-235 activity ratio for slightly enriched (2 percent) uranium is approximately 8 and approximately 0.01 for highly enriched (greater than 93 percent) uranium.

### 3.12.1 Waste Zone

Eighteen waste zone lysimeters were sampled every quarter in FY 2004 and Lysimeters 741-08-L1 and 743-18-L2, located in Pits 10 and 4, respectively, were the only waste zone lysimeters to yield samples. Uranium-233/234, U-235/236, and U-238 analyses were performed on these samples, with two positive detections (see Table 3-43).

Table 3-43. Uranium detections above background in Fiscal Year 2004 Subsurface Disposal Area waste zone samples.

Radionuclide	Sample Date	Well: Lysimeter	Lysimeter Depth (ft)	Sample Result $\pm 1\sigma$ (pCi/L)	MDC (pCi/L)	Local Soil Moisture Background (pCi/L)	RBC <sup>b</sup> (pCi/L)
U-233/234	06/22/04	743-18-L2	12.8	<b>19 <math>\pm 4</math><sub>J</sub><sup>c</sup></b>	5	3.5	6.74
U-235/236	06/22/04	743-18-L2	12.8	<b>8.4 <math>\pm 2.6</math><sup>c</sup></b>	5	0.7	6.63

a. Local soil-moisture background concentrations for uranium isotopes are defined as the mean plus the standard deviation of the mean of 76 soil-moisture samples collected between 1998 and August 2004 from the "O" and D15 lysimeter wells located outside of the SDA.

b. RBC = 1E-05 for drinking water. The RBCs for the aquifer are provided here as a basis of comparison.

c. **Red bold font** indicates sample concentrations that exceed the RBC (see Footnote b). Concentration values with a "J" subscript denote that "J" data validation qualifier flags were assigned. The "J" flag was assigned to the U-233/234 result because the lab blank was statistically positive (i.e., results  $>2\sigma$  and  $<3\sigma$ ). The result is usable, but should only be used as an estimated quantity.

MDC = minimum detectable concentration

RBC = risk-based concentration

SDA = Subsurface Disposal Area

### 3.12.2 Vadose Zone

#### 3.12.2.1 Subsurface Soil Samples Collected While Drilling Lysimeter Well RWMC-2005.

In April 2004, while drilling Lysimeter Well RWMC-2005 in the east end of the SDA (see Figure 2-3), radioactivity above background was detected in the drilling soil returns. Drilling was stopped and three

separate soil samples were collected from these returns. The samples were analyzed for U-233/234, U-235/236, and U-238, and no positive detections were observed above surficial soil background upper 95 percent tolerance concentration limits (UTLs).

**3.12.2.2 Lysimeter Samples at Depths of 0–35 ft.** Seventy-two isotopic uranium analyses were performed on soil-moisture samples collected from nine shallow lysimeters in and around the SDA in FY 2004, with 50 detections above local soil-moisture background (see Table 3-44). Of the 50 results above background, 28 exceeded the aquifer 1E-05 RBC.

Table 3-44. Isotopic uranium results above local soil-moisture background in the 0–35-ft depth interval.

Radionuclide	Sample Date	Well: Lysimeter	Well: Lysimeter Depth (ft)	Sample Result (pCi/L)	MDC (pCi/L)	Local Soil-Moisture Background <sup>a</sup> (pCi/L)	RBC <sup>b</sup> (pCi/L)
U-233/234	10/28/03	PA01:L15	14.3	<b>35 ± 4<sup>c</sup></b>	1.6	3.5	6.74
	10/28/03	PA02:L16	8.7	<b>34 ± 4<sup>c</sup></b>	1.7	3.5	6.74
	10/27/03	W08:L13	11.3	<b>25 ± 3<sup>c</sup></b>	1.4	3.5	6.74
	10/27/03	W23:L07	18.8	<b>85 ± 9<sup>c</sup></b>	1.9	3.5	6.74
	10/28/03	W25:L28	15.5	<b>4.7 ± 1.0<sup>d</sup></b>	1.7	3.5	6.74
	10/27/03	98-5:L39	10.5	<b>10.3 ± 1.6<sup>c</sup></b>	1.2	3.5	6.74
	01/26/04	PA02:L16	8.7	<b>33 ± 3<sup>c</sup></b>	0.5	3.5	6.74
	01/26/04	W08:L13	11.3	<b>19 ± 2<sup>c</sup></b>	1.3	3.5	6.74
	01/28/04	W25:L28	15.5	<b>3.8 ± 0.8<sup>d</sup></b>	0.9	3.5	6.74
	05/04/04	PA02:L16	8.7	<b>23 ± 3<sup>c</sup></b>	1.7	3.5	6.74
	05/05/04	W23:L07	18.8	<b>72 ± 7<sup>c</sup></b>	1.5	3.5	6.74
	05/05/04	W23:L09	7.7	<b>19 ± 3<sup>c</sup></b>	1.4	3.5	6.74
	05/05/04	98-4:L38	17.0	<b>3.8 ± 0.9<sup>d</sup></b>	1.0	3.5	6.74
	08/30/04	PA01:L15	14.3	<b>44 ± 4<sup>c</sup></b>	1.2	3.5	6.74
	08/30/04	PA02:L16	8.9	<b>20 ± 2<sup>c</sup></b>	1.4	3.5	6.74
	08/23/04	W09:L23	14.8	<b>5.0 ± 0.9<sup>d</sup></b>	1.2	3.5	6.74
	08/23/04	W23:L07	18.8	<b>59 ± 5<sup>c</sup></b>	0.9	3.5	6.74
	08/23/04	W23:L09	7.7	<b>55 ± 5<sup>c</sup></b>	1.6	3.5	6.74
	08/25/04	W25:L28	15.5	<b>4.0 ± 0.9<sup>d</sup></b>	1.2	3.5	6.74
	08/25/04	98-4:L38	17.0	<b>4.3 ± 0.8<sup>d</sup></b>	1.2	3.5	6.74
U-235/236	10/28/03	PA01:L15	14.3	<b>4.8 ± 1.1<sup>d</sup></b>	1.3	0.7	6.63
	10/28/03	PA02:L16	8.7	<b>2.5 ± 0.8<sup>d</sup></b>	1.7	0.7	6.63
	10/27/03	W08:L13	11.3	<b>2.5 ± 0.7<sup>d</sup></b>	1.4	0.7	6.63
	10/27/03	W23:L07	18.8	<b>4.0 ± 1.0<sup>d</sup></b>	1.9	0.7	6.63
	01/26/04	PA02:L16	8.7	<b>2.1 ± 0.6<sup>d</sup></b>	1.2	0.7	6.63
	05/04/04	PA02:L16	8.7	<b>2.9 ± 0.9<sup>d</sup></b>	1.4	0.7	6.63
	05/05/04	W23:L07	18.8	<b>4.0 ± 1.0<sup>d</sup></b>	1.1	0.7	6.63
	08/23/04	W23:L07	18.8	<b>2.8 ± 0.7<sup>d</sup></b>	1.0	0.7	6.63
	08/23/04	W23:L09	7.7	<b>2.2 ± 0.6<sup>d</sup></b>	1.1	0.7	6.63

Table 3-44. (continued).

Radionuclide	Sample Date	Well: Lysimeter	Well: Lysimeter Depth (ft)	Sample Result (pCi/L)	MDC (pCi/L)	Local Soil-Moisture Background <sup>a</sup> (pCi/L)	RBC <sup>b</sup> (pCi/L)
U-238	10/28/03	PA01:L15	14.3	<b>16 ± 2<sup>c</sup></b>	1.1	1.8	5.47
	10/28/03	PA02:L16	8.7	<b>15 ± 2<sup>c</sup></b>	1.6	1.8	5.47
	10/27/03	W08:L13	11.3	<b>15 ± 2<sup>c</sup></b>	1.6	1.8	5.47
	10/27/03	W23:L07	18.8	<b>51 ± 6<sup>c</sup></b>	1.8	1.8	5.47
	10/28/03	W25:L28	15.5	<b>3.3 ± 0.8<sup>d</sup></b>	1.4	1.8	5.47
	10/27/03	98-5:L39	10.5	<b>8.0 ± 1.4<sup>c</sup></b>	1.0	1.8	5.47
	01/26/04	PA02:L16	8.7	<b>16 ± 2<sup>c</sup></b>	0.8	1.8	5.47
	01/26/04	W08:L13	11.3	<b>11.6 ± 1.6<sup>c</sup></b>	1.1	1.8	5.47
	01/28/04	W25:L28	15.5	<b>2.2 ± 0.6<sup>d</sup></b>	0.4	1.8	5.47
	05/03/04	PA02:L16	8.7	<b>11.0 ± 1.9<sup>c</sup></b>	1.7	1.8	5.47
	05/05/04	W23:L07	18.8	<b>41 ± 4<sup>c</sup></b>	1.3	1.8	5.47
	05/05/04	W23:L09	7.7	<b>9.4 ± 1.5<sup>c</sup></b>	1.2	1.8	5.47
	05/05/04	W25:L28	15.5	<b>2.2 ± 0.7<sup>d</sup></b>	1.2	1.8	5.47
	05/05/04	98-4:L38	17.0	<b>3.1 ± 0.8<sup>d</sup></b>	1.0	1.8	5.47
	08/30/04	PA01:L15	14.3	<b>21 ± 2<sup>c</sup></b>	1.2	1.8	5.47
	08/30/04	PA02:L16	8.9	<b>10.9 ± 1.4<sup>c</sup></b>	0.9	1.8	5.47
	08/23/04	W09:L23	14.8	<b>2.7 ± 0.6<sup>d</sup></b>	0.8	1.8	5.47
	08/23/04	W23:L07	18.8	<b>37 ± 4<sup>c</sup></b>	1.3	1.8	5.47
	08/23/04	W23:L09	7.7	<b>32 ± 3<sup>c</sup></b>	1.0	1.8	5.47
	08/25/04	W25:L28	15.5	<b>3.4 ± 0.8<sup>d</sup></b>	1.2	1.8	5.47
	08/25/04	98-4:L38	17.0	<b>2.1 ± 0.5<sup>d</sup></b>	0.7	1.8	5.47
<p>a. Local soil-moisture background concentrations for uranium isotopes are defined as the mean plus the standard deviation of the mean, of 76 soil-moisture samples collected between 1998 and August 2004 from the "O" and D15-series lysimeter wells located outside of the SDA.</p> <p>b. RBC = 1E-05 for drinking water. The RBCs for the aquifer are provided here as a basis of comparison.</p> <p>c. <b>Red bold font</b> indicates sample concentrations that exceed the 1E-05 RBC (see Footnote b).</p> <p>d. <b>Black bold font</b> indicates sample concentrations less than the MCL, but exceeding local soil-moisture background concentrations (see Footnote</p> <p>MDC = minimum detectable concentration  RBC = risk-based concentration  SDA = Subsurface Disposal Area</p>							

Concentrations of U-233/234, U-235/236, and U-238 in the 0–11-m (0–35-ft) depth interval during FY 2004 remained relatively constant in most but not all shallow lysimeter locations. The concentrations in Wells PA01, PA02, W08, and W23 continue to remain very elevated and above 1E-05 RBCs (see Figures 3-52a, 3-52b, and 3-52c). Uranium-234 concentrations increased in Well PA01, and decreased in PA02 and W23. Uranium-235 concentrations decreased in Well PA01, PA02, and W23 lysimeters; whereas, U-238 concentrations remained relatively constant in these lysimeters. The variation in isotopic concentrations, especially those observed in August 2004, affected the long-term U238:U235 activity ratio trends on PA01, PA02, and W23 (see Figures 3-53a, 3-53b, and 3-53c). A sample was not collected from Well W08 in August 2004; therefore, the U238:U235 ratio did not change (see Figure 3-53d). Until the conditions that caused changes in isotopic concentrations and their associated ratios are understood, or until more monitoring data can be acquired, the uranium at these monitoring locations will be treated as anthropogenic uranium with a slight U-235 enrichment.

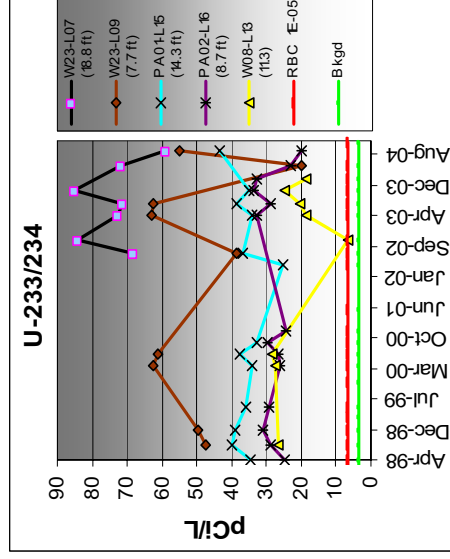


Figure 3-52a. Uranium-233/234 in select lysimeters from the shallow vadose zone, April 1998 through August 2004.

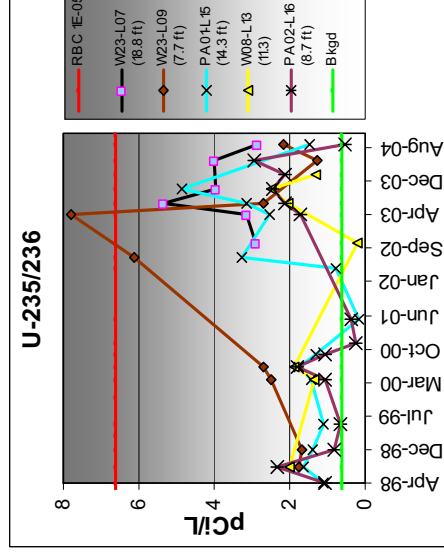


Figure 3-52b. Uranium-235/236 in select lysimeters from the shallow vadose zone, April 1998 through August 2004.

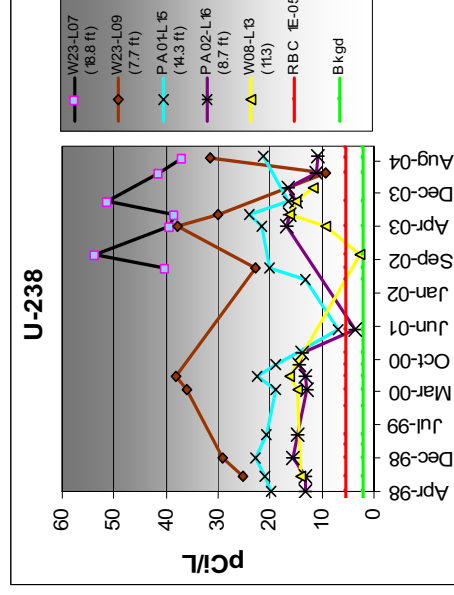


Figure 3-52c. Uranium-238 in select lysimeters from the shallow vadose zone, April 1998 through August 2004.



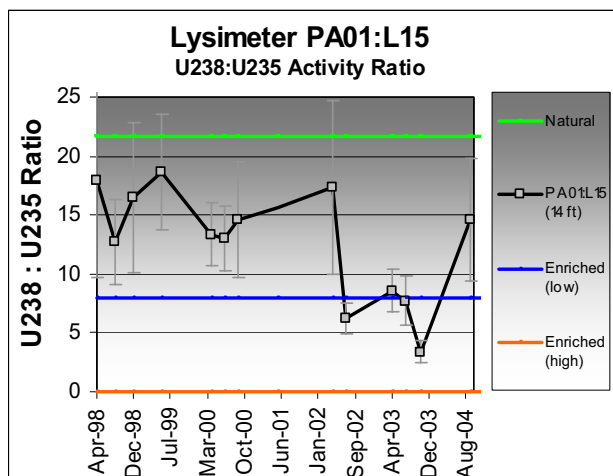


Figure 3-53a. Uranium-238:235 activity ratios for the PA01:L15 shallow lysimeter from April 1998 through August 2004.

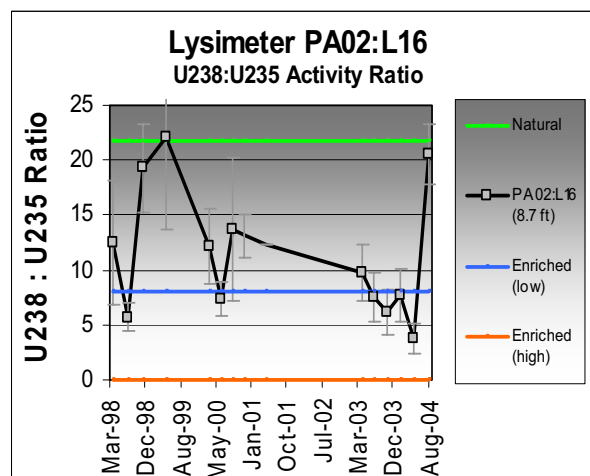


Figure 3-53b. Uranium-238:235 activity ratios for the PA02:L16 shallow lysimeter from April 1998 through August 2004.

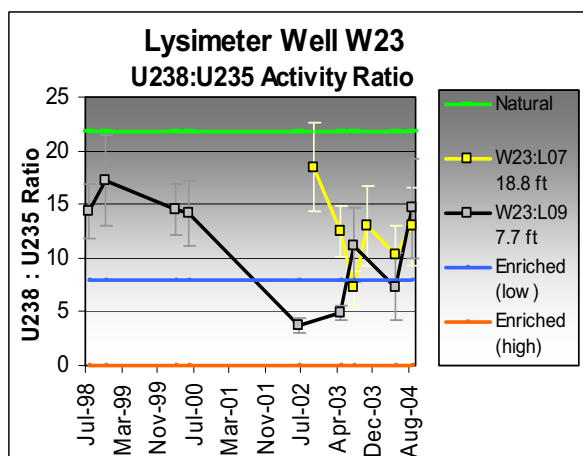


Figure 3-53c. Uranium-238:235 activity ratios for the W23:L07 and W23:L09 shallow lysimeters from August 1998 through August 2004.

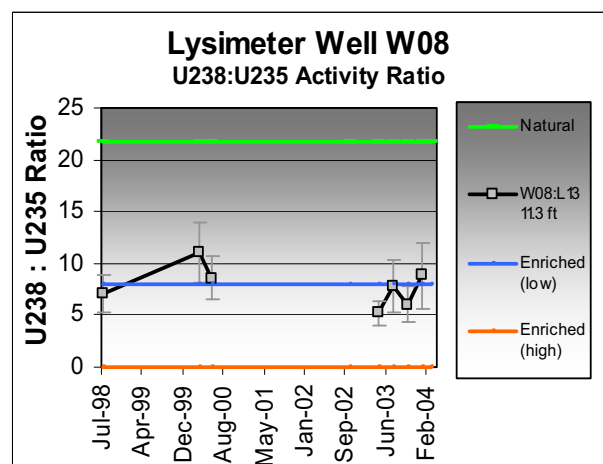


Figure 3-53d. Uranium-238:235 activity ratios for the W08:L13 shallow lysimeters from August 1998 through February 2004.

Even though the historical U238:U235 activity ratios are suggestive of slightly enriched uranium, the U-234:U-238 ratios are more indicative of natural uranium. The U234:U238 activity ratios for these shallow lysimeters are approximately 2:1, which is drastically different than the 10:1 ratio associated with Lysimeter TW1:DL04 where enriched uranium is known to be present. The U234:U238 ratio of approximately 2:1 is typical of natural activity in RWMC groundwater and vadose zone soil moisture. Because records show significant quantities of depleted uranium were buried in the SDA, it is conjectured that associated U-238 might be interfering with an accurate interpretation of isotopic uranium ratios. A soil-moisture sample was collected the first quarter of FY 2005, from a location at this depth interval suspected of containing anthropogenic uranium (i.e., PA01), and was sent to RTC for analysis by inductively coupled plasma/mass spectrometry (ICP/MS). This analytical methodology is capable of



detecting extremely low concentrations with very high precision, and will accurately quantify U-235 and identify U-236, thus confirming the presence of anthropogenic uranium and its U-235 enrichment.

**3.12.2.2.1 Lysimeter Samples at Depths of 35–140 ft**—One hundred and eight isotopic uranium analyses were performed on soil-moisture samples collected from 13 lysimeters in and around the SDA in FY 2004, with 44 detections above local soil-moisture background (see Table 3-45). Of the 44 results above background, 29 exceeded the 1E-05 RBC for the aquifer.

Table 3-45. Isotopic uranium results above local soil-moisture background in the 35–140-ft depth interval.

Radionuclide	Sample Date	Well: Lysimeter	Well: Lysimeter Depth (ft)	Sample Result (pCi/L)	MDC (pCi/L)	Local Soil-Moisture Background <sup>a</sup> (pCi/L)	RBC <sup>b</sup> (pCi/L)
U-233/234	10/28/03	D06:DL01	88	<b><math>87 \pm 8^c</math></b>	2.3	3.5	6.74
	10/28/03	D06:DL02	44	<b><math>99 \pm 10^c</math></b>	1.7	3.5	6.74
	10/27/03	I-1S:DL09	101	<b><math>13.6 \pm 1.9^c</math></b>	1.8	3.5	6.74
	10/27/03	I-4S:DL15	97	<b><math>6.8 \pm 1.2^c</math></b>	1.4	3.5	6.74
	10/28/03	TW1:DL04	101.7	<b><math>96 \pm 9^c</math></b>	1.2	3.5	6.74
	01/28/04	I-1S:DL09	101	<b><math>9.3 \pm 1.4^c</math></b>	1.1	3.5	6.74
	01/26/04	I-4S:DL15	97	<b><math>10.8 \pm 1.5^c</math></b>	1.3	3.5	6.74
	01/27/04	O-2:DL20	106	<b><math>5.0 \pm 1.0^d</math></b>	1.0	3.5	6.74
	05/03/04	D06:DL01	88.0	<b><math>91 \pm 8^c</math></b>	0.6	3.5	6.74
	05/03/04	D06:DL02	44.0	<b><math>105 \pm 10^c</math></b>	1.4	3.5	6.74
	05/04/04	I-1S:DL09	101	<b><math>15 \pm 2^c</math></b>	1.3	3.5	6.74
	05/04/04	I-3S:DL13	93	<b><math>4.3 \pm 1.0^d</math></b>	1.3	3.5	6.74
	05/04/04	I-4S:DL15	97	<b><math>11.6 \pm 1.7^c</math></b>	1.2	3.5	6.74
	05/05/04	O-2:DL20	106	<b><math>3.8 \pm 0.9^d</math></b>	1.2	3.5	6.74
	05/03/04	TW1:DL04	101.7	<b><math>93 \pm 8^c</math></b>	0.9	3.5	6.74
	08/26/04	D06:DL01	88	<b><math>84 \pm 6^c</math></b>	0.8	3.5	6.74
	08/25/04	I-1S:DL09	101	<b><math>17 \pm 2^c</math></b>	1.6	3.5	6.74
	08/25/04	I-3S:DL13	93	<b><math>4.0 \pm 0.9^d</math></b>	1.1	3.5	6.74
	08/23/04	TW1:DL04	101.7	<b><math>121 \pm 10^c</math></b>	1.9	3.5	6.74
U-235/236	10/28/03	D06:DL02	44	<b><math>9.4 \pm 1.5^c</math></b>	1.7	0.7	6.63
	10/27/03	TW1:DL04	101.7	<b><math>6.3 \pm 1.2^d</math></b>	1.0	0.7	6.63
	05/03/04	D06:DL01	88.0	<b><math>4.5 \pm 1.0^d</math></b>	0.6	0.7	6.63
	05/03/04	D06:DL02	44.0	<b><math>2.9 \pm 0.8^d</math></b>	1.4	0.7	6.63
	05/03/04	TW1:DL04	101.7	<b><math>8.8 \pm 1.4^c</math></b>	1.0	0.7	6.63
	08/26/04	D06:DL01	88	<b><math>2.8 \pm 0.6^d</math></b>	0.7	0.7	6.63
	08/23/04	TW1:DL04	101.7	<b><math>5.1 \pm 1.1^d</math></b>	1.3	0.7	6.63

Table 3-45. (continued).

Radionuclide	Sample Date	Well: Lysimeter	Well: Lysimeter Depth (ft)	Sample Result (pCi/L)	MDC (pCi/L)	Local Soil-Moisture Background <sup>a</sup> (pCi/L)	RBC <sup>b</sup> (pCi/L)
U-238	10/28/03	D06:DL01	88	<b>42 ± 5<sup>c</sup></b>	2.3	1.8	5.47
	10/28/03	D06:DL02	44	<b>48 ± 5<sup>c</sup></b>	1.3	1.8	5.47
	10/27/03	I-1S:DL09	101	<b>8.8 ± 1.4<sup>c</sup></b>	1.4	1.8	5.47
	10/28/03	I-3S:DL13	93	<b>2.2 ± 0.6<sup>d</sup></b>	0.7	1.8	5.47
	10/28/03	I-4S:DL15	97	<b>4.3 ± 0.9<sup>d</sup></b>	1.3	1.8	5.47
	10/27/03	TW1:DL04	101.7	<b>7.8 ± 1.4<sup>c</sup></b>	1.2	1.8	5.47
	01/28/04	I-1S:DL09	101	<b>4.8 ± 0.9<sup>d</sup></b>	1.0	1.8	5.47
	01/26/04	I-4S:DL15	97	<b>4.2 ± 0.8<sup>d</sup></b>	1.1	1.8	5.47
	05/03/04	D06:DL01	88.0	<b>48 ± 5<sup>c</sup></b>	1.0	1.8	5.47
	05/03/04	D06:DL02	44.0	<b>45 ± 5<sup>c</sup></b>	1.3	1.8	5.47
	05/04/04	I-1S:DL09	101	<b>12.0 ± 1.8<sup>c</sup></b>	0.6	1.8	5.47
	05/04/04	I-3S:DL13	93	<b>3.1 ± 0.9<sup>d</sup></b>	1.4	1.8	5.47
	05/04/04	I-4S:DL15	97	<b>6.0 ± 1.1<sup>c</sup></b>	1.1	1.8	5.47
	05/05/04	O-2:DL20	106	<b>3.2 ± 0.8<sup>d</sup></b>	1.3	1.8	5.47
	05/03/04	TW1:DL04	101.7	<b>10.3 ± 1.5<sup>c</sup></b>	0.9	1.8	5.47
	08/26/04	D06:DL01	88	<b>47 ± 4<sup>c</sup></b>	0.4	1.8	5.47
	08/25/04	I-1S:DL09	101	<b>8.4 ± 1.5<sup>c</sup></b>	1.4	1.8	5.47
	08/25/04	I-3S:DL13	93	<b>3.3 ± 0.8<sup>d</sup></b>	0.5	1.8	5.47
	08/23/04	TW1:DL04	101.7	<b>15 ± 2<sup>c</sup></b>	1.8	1.8	5.47
<p>a. Local soil-moisture background concentrations for uranium isotopes are defined as the mean plus the standard deviation of the mean, of 76 soil-moisture samples collected between 1998 and August 2004 from the "O" and D15-series lysimeter wells located outside of the SDA.</p> <p>b. RBC = 1E-05 for drinking water. The RBCs for the aquifer are provided here as a basis of comparison.</p> <p>c. <b>Red bold font</b> indicates sample concentrations that exceed the 1E-05 RBC (see Footnote b).</p> <p>d. <b>Black bold font</b> indicates sample concentrations less than the MCL, but exceeding local soil-moisture background concentrations (see Footnote b).</p> <p>MDC = minimum detectable concentration  RBC = risk-based concentration  SDA = Subsurface Disposal Area</p>							

Isotopic uranium concentrations in the SDA at intermediate depths during FY 2004 appear fairly constant at most lysimeter locations; however, the isotopic concentrations varied from historical concentrations in a few lysimeters. The concentrations in Wells D06, I1S, and TW1 continue to remain very elevated and above 1E-05 RBCs (see Figures 3-54a, 3-54b and 3-54c). The U-233/234 and U-238 concentrations at Well I4S are slightly above RBCs, and increasing. Uranium-235/236 concentrations in Well I4S are near the detection limit, and therefore do not provide usable information with which to assess the source of uranium at this time. Because uranium concentrations in Well I4S are relatively low, compared to D06 and TW1, a separate graph was prepared to better illustrate the concentration trend (see Figure 3-54d). Uranium-233/234 concentrations increased in Wells D06:DL02 and TW1:DL04, but remained constant in Well I1S and decreased slightly in Well D06:DL01; whereas, U-235/236 concentrations decreased in Wells D06:DL01, D06:DL02, and TW1:DL04, but also remained constant in

Well IIS. Uranium-238 remained relatively constant in Well D06:DL01, D06:DL02, and IIS, but increased slightly in Well TW1. Needless to say, the uranium dynamics at these lysimeter locations are difficult to understand. The decrease in U-235/236 concentrations at locations Wells D06:DL01 and D06:DL02 this fiscal year changed the U238:U235 activity ratios significantly (see Figure 3-55a); however, the ratio only changed moderately in Well TW1 with little overall affect (see Figure 3-55b). The change in uranium concentrations and their isotopic ratios at Well D06 are conjectured to be due to infiltration of runoff water. After construction of the Accelerated Retrieval Project structures, the region where monitoring Well D06 is located became the termination point for runoff water. The area has been flooded recently, and standing water levels were near the tops of the well heads.

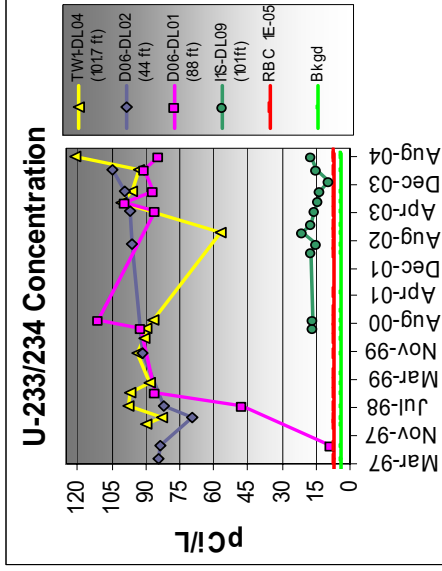


Figure 3-54a. Uranium-233/234 in mid-depth lysimeters, March 1997 through August 2004.

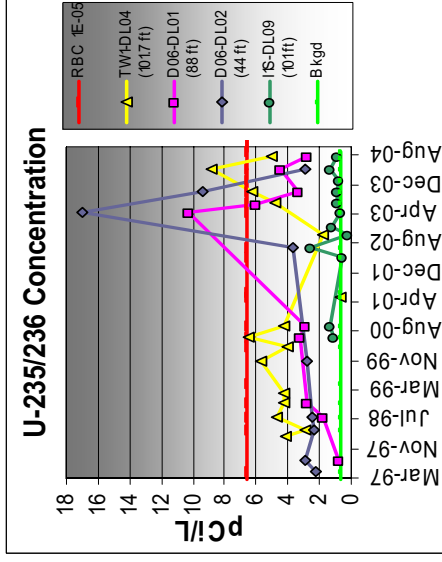


Figure 3-54b. Uranium-235/236 in mid-depth lysimeters, March 1997 through August 2004.

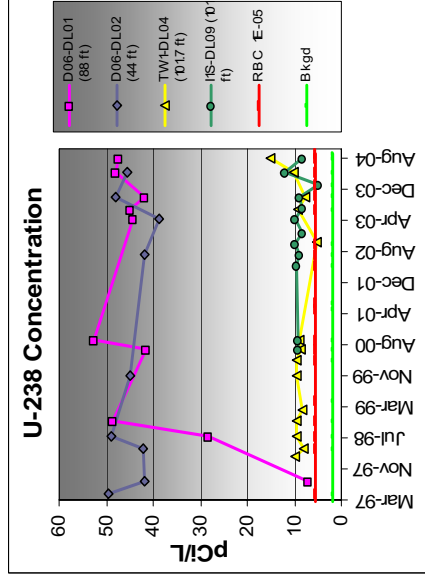


Figure 3-54c. Uranium-238 in mid-depth lysimeters, March 1997 through August 2004.

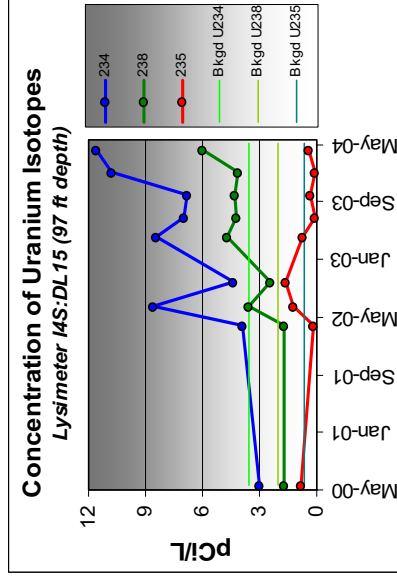


Figure 3-54d. Concentration of uranium isotopes in mid-depth lysimeter I4S:DL15, May 2000 through May 2004.

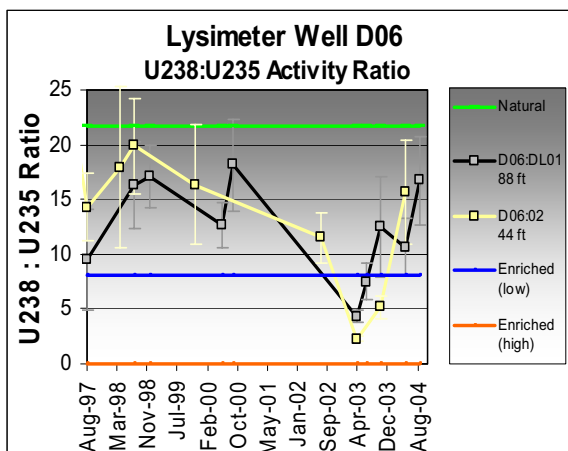


Figure 3-55a. Uranium-238:235 activity ratio in D06:DL01 and D06:DL02 over time.

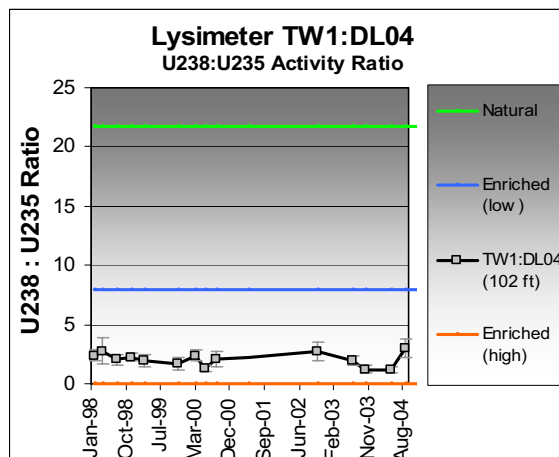


Figure 3-55b. Uranium-238:235 activity ratio in TW1:DL04 over time.

Even though the historical U238:U235 activity ratios for Well D06 are suggestive of slightly enriched uranium, the U234:U238 ratios are more indicative of natural uranium. The U234:U238 activity ratios for Wells D06 and I1S are approximately 2:1, which is drastically different than the 10:1 ratio associated with Lysimeter TW1:DL04, where enriched uranium is known to be present. The U234:U238 ratio of approximately 2:1 is typical of natural activity in RWMC groundwater and vadose zone soil moisture. Because records show significant quantities of depleted uranium were buried in the SDA, it is conjectured that its U-238 might be interfering with an accurate interpretation of isotopic uranium ratios. Soil moisture samples were collected the first quarter of FY 2005, at locations suspected of containing anthropogenic uranium (i.e., Wells D06 and TW1), and were sent to the RTC for analysis by ICP/MS. This analytical methodology is capable of detecting extremely low concentrations with very high precision, and will accurately quantify U-235 and identify U-236, thus confirming the presence of anthropogenic uranium and its U-235 enrichment. Trends are not apparent in other intermediate depth lysimeters in the SDA, except for Well I4S:DL15. Although uranium concentrations in Well I4S:DL15 are not as high as the shallower lysimeters, it does provide additional evidence of uranium migration in this area of the SDA. Although all uranium isotopes measured in Well I1S on the west end of the SDA are relatively high, there are no notable concentration trends. Well I1S is located near Well W23, which yielded samples high in uranium from the shallow vadose zone.

**3.12.2.3 Lysimeter and Perched Water Samples Deeper than 140 ft.** One hundred seventy-four isotopic uranium analyses were performed on soil-moisture and perched water samples collected from 16 lysimeters and three perched wells in and around the SDA in FY 2004, with 24 detections above local soil-moisture background (see Table 3-46). Of the 24 detections above soil-moisture background, eight exceeded the  $1\text{E-}05$  RBC for the aquifer. It does not appear as though there has been an anthropogenic impact to soil moisture at this depth and location within the SDA, other than Well TW1:DL03 at 69 m (227 ft). This is the first time a soil-moisture sample has been collected from Well TW1:DL03, and interesting that the uranium concentrations and isotopic ratios are very similar to Well TW1:DL04 at 31 m (102 ft) in the same well, which is known to contain anthropogenic uranium with a slight U-235 enrichment. One sample result, however, is not sufficient evidence to surmise anthropogenic uranium has migrated to 69 m (227 ft), especially since there is a remote possibility that the DL03 and DL04 sample lines could have been switched during this sampling event, or the samples could have been mislabeled. Wells IE3 and IE7 also have elevated U-234 and U-238 concentrations, but no U-235 detections. The U234:U238 activity ratios for Wells IE3 and IE7 are not characteristic of soil

moisture encountered at other lysimeter locations. The U234:U238 activity ratio for Well IE3 is approximately 1:1, which is characteristic of natural uranium in rock and soil, but not in soil moisture. The U234:U238 activity ratio at Well IE7 is approximately 3:1, which is higher than normally experienced in soil moisture. Because the “IE-series” monitoring wells are fairly new, more time and a few more sampling events will be required before lysimeters equilibrate with their surroundings and produce representative samples. Lysimeter locations that exceeded U-233/234 and U-238 MCLs in FY 2004, as well as the historical U-233/234 and U-238 data from Well USGS-92 (65 m [214 ft] deep) are depicted in Figures 3-56a and 3-56b. A number of lysimeter and perched water samples routinely exceed background concentrations for U-233/234 and U-238; however, the data at this point show no constant trends.

Table 3-46. Isotopic uranium results above local soil-moisture background at depths greater than 140 ft.

Radionuclide	Sample Date	Well: Lysimeter	Well: Lysimeter Depth (ft)	Sample Result (pCi/L)	MDC (pCi/L)	Local Soil-Moisture Background <sup>a</sup> (pCi/L)	RBC <sup>b</sup> (pCi/L)
U-233/234	10/28/03	IE3:DL30	225	<b>7.2 ± 1.3<sup>c</sup></b>	1.5	3.5	6.74
	10/29/03	O-2:DL19	240	<b>4.8 ± 1.1<sup>d</sup></b>	1.6	3.5	6.74
	10/29/03	O-7:DL27	240	<b>6.2 ± 1.2<sup>d</sup></b>	1.2	3.5	6.74
	01/27/04	IE3:DL30	225	<b>7.9 ± 1.1<sup>c</sup></b>	0.6	3.5	6.74
	01/26/04	IE4:DL32	223	<b>3.7 ± 0.8<sup>d</sup></b>	1.3	3.5	6.74
	01/26/04	TW1:DL03	226.9	<b>84 ± 8<sup>c</sup></b>	1.0	3.5	6.74
	05/04/04	IE3:DL30	225	<b>4.2 ± 1.0<sup>c</sup></b>	0.6	3.5	6.74
	05/04/04	IE7:DL35	231	<b>10.1 ± 1.6<sup>c</sup></b>	1.5	3.5	6.74
	08/25/04	I-2D:DL10	196	<b>5.2 ± 0.9<sup>d</sup></b>	0.7	3.5	6.74
	08/30/04	IE7:DL35	231	<b>12 ± 2<sup>c</sup></b>	1.7	3.5	6.74
	08/30/04	O-7:DL27	240	<b>5.1 ± 0.9<sup>d</sup></b>	0.8	3.5	6.74
	08/26/04	USGS-092	214	<b>3.8 ± 0.8<sup>d</sup></b>	1.2	3.5	6.74
U-235/236	01/26/04	TW1:DL03	226.9	<b>4.5 ± 0.9<sup>d</sup></b>	0.9	0.7	6.63
U-238	10/28/03	IE3:DL30	225	<b>7.8 ± 1.4<sup>c</sup></b>	1.4	1.8	5.47
	10/28/03	IE4:DL32	223	<b>2.4 ± 0.6<sup>d</sup></b>	0.8	1.8	5.47
	10/29/03	O-7:DL27	240	<b>2.5 ± 0.7<sup>d</sup></b>	1.4	1.8	5.47
	01/27/04	IE3:DL30	225	<b>7.4 ± 1.1<sup>c</sup></b>	0.3	1.8	5.47
	01/26/04	TW1:DL03	226.9	<b>8.7 ± 1.3<sup>c</sup></b>	1.0	1.8	5.47
	05/04/04	IE3:DL30	225	<b>3.2 ± 0.8<sup>d</sup></b>	0.6	1.8	5.47
	05/04/04	IE7:DL35	231	<b>2.8 ± 0.8<sup>d</sup></b>	1.3	1.8	5.47
	08/26/04	88-02D	220	<b>3.3 ± 0.8<sup>d</sup></b>	0.6	1.8	5.47
	08/31/04	DE4:DL33	463	<b>2.4 ± 0.6<sup>d</sup></b>	0.9	1.8	5.47
	08/30/04	IE7:DL35	231	<b>4.3 ± 1.2<sup>d</sup></b>	2.0	1.8	5.47
	08/30/04	O-7:DL27	240	<b>2.8 ± 0.7<sup>d</sup></b>	1.3	1.8	5.47

a. Local soil-moisture background concentrations for uranium isotopes are defined as the mean plus the standard deviation of the mean, of 76 soil-moisture samples collected between 1998 and August 2004 from the “O” and D15-series lysimeter wells located outside of the SDA.

b. RBC = 1E-05 for drinking water. The RBCs for the aquifer are provided here as a basis of comparison.

c. **Red bold font** indicates sample concentrations that exceed the 1E-05 RBC (see Footnote b).

d. **Black bold font** indicates sample concentrations less than the MCL, but exceeding local soil-moisture background concentrations (see Footnote a).

MDC = minimum detectable concentration

RBC = risk-based concentration

SDA = Subsurface Disposal Area

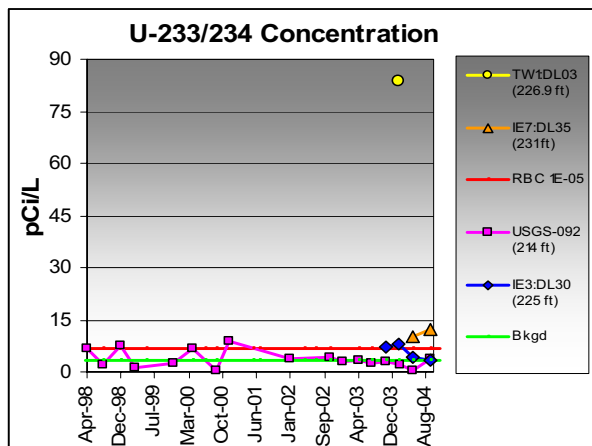


Figure 3-56a. Uranium-233/234 data from wells that have exceeded the U-234 maximum contaminant level, April 1998 through August 2004.

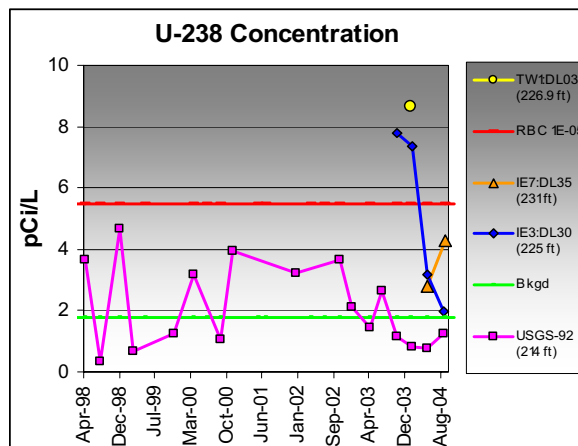


Figure 3-56b. Uranium-238 data from wells that have exceeded maximum contaminant levels, April 1998 through August 2004.

**3.12.2.4 Interbed Cores Samples at Depths from 100–250 ft.** Thirteen U-233/234, U-235/236, and U-238 analyses were performed on interbed core samples collected from five wells drilled in the SDA during FY 2003, resulting in one positive detection above background concentrations. Isotopic uranium results were compared to surficial soil background UTLs. Surficial soil background tolerance limits were established in 1996 (Rood, Harris, and White 1996), and are not necessarily applicable to subsurface sediments, but used here only as a basis for comparison.

Uranium-238:U235 and U234:U238 activity ratios also were evaluated to determine whether there were anthropogenic influences at these depths and sample locations. Activity ratios of U234:U238 varied from 0.74 to 1.05 and U-238:U-235 ratios varied from 4.9 to 25.4. A U238:U235 activity ratio of 4.9 is indicative of anthropogenic uranium, because the ratio of naturally occurring uranium is about 22:1. The lower the U238:U235 activity ratio is from 22:1, the higher the U-235 enrichment. Ratios around 8:1 are indicative of about 2 percent enriched uranium, and ratios near 0.01:1 are indicative of highly enriched uranium (i.e., approximately 93 percent U-235). The suspect sample is from the C-D interbed at core location DE-4, which is located near Pad A (see Figure 2-6). Anthropogenic uranium at this depth and location is not surprising, because soil-moisture samples from this area (Wells PA01, PA02, D06, and TW1) also indicate anthropogenic uranium. And with uranium concentrations beginning to increase in soil moisture at the adjacent I4S location, the evidence that uranium contamination is extensive in this area of the SDA is mounting. The detected uranium in this area of the SDA has numerous anthropogenic indicators; however, it may be possible that magnesium chloride brine is altering the geochemistry and causing substantial amounts of natural uranium to be preferentially leached from the surrounding soil, basalt, and sediments.

### 3.12.3 Aquifer

One hundred and forty-one isotopic uranium analyses were performed on aquifer samples collected from 15 monitoring wells in the vicinity of the RWMC in FY 2004, with six positive detections above background. All isotopic uranium concentrations were within concentration ranges typically observed in the aquifer, with the exception of five U-235/236 results and one U-233/234 result (see Table 3-47). None of the results exceeded the 1E-05 aquifer RBCs for each uranium isotope. The elevated U-233/234 and U-235/236 concentrations were measured in samples collected from monitoring Wells M7S, M12S,



M14S, and OW2. Variations in concentration for Wells M7S and M14S are generally typical of background fluctuations; whereas, concentrations for Well OW2 vary considerably, but show no evidence of a trend. A U-235/236 concentration trend may be developing in Well M12S, along with trending U238:U235 activity ratios (see Figures 3-57a, 3-57b, and 3-57c). Such trends probably are not associated with natural uranium in the aquifer, but rather with anthropogenic uranium. Well M12S is located about 4.8 km (3 mi) downgradient of INTEC, where very low concentrations of anthropogenic uranium have been detected in the aquifer in the past. Four monitoring wells downgradient of INTEC were cited in an aquifer background investigation report as containing U-236 and isotopic uranium ratios that unequivocally indicate a component of anthropogenic uranium (Roback 2002) (see well locations in Figure 3-58). Thus, the uranium in Well M12S may be anthropogenic and may originate from INTEC. A concentration trend also could be developing in Well M13S (see Figures 3-59a and 3-59b); however, more time and data are necessary to make a proper determination. Other reasons for the increasing levels of U-235 are discussed below.

Table 3-47. Isotopic uranium results above aquifer background levels.

Radionuclide	Sample Date	Well	Sample Result $\pm 1\sigma$ (pCi/L)	MDC (pCi/L)	Aquifer Background <sup>a</sup> (pCi/L)	RBC <sup>b</sup> ( $\mu$ g/L)
U-233/234	05/03/04	OW2	<b>2.08 <math>\pm</math> 0.18<sup>c</sup></b>	0.06	1.92	6.74
U-235/236	12/02/03	OW2	<b>0.22 <math>\pm</math> 0.03<sup>c</sup></b>	0.04	0.15	6.63
U-235/236	12/02/03	OW2	<b>0.11 <math>\pm</math> 0.03<sup>c,d</sup></b> (duplicate sample)	0.04	0.15	6.63
U-235/236	01/20/04	M7S	<b>0.16 <math>\pm</math> 0.03<sup>c</sup></b>	0.04	0.15	6.63
U-235/236	04/26/04	M12S	<b>0.22 <math>\pm</math> 0.04<sup>c</sup></b>	0.04	0.15	6.63
U-235/236	04/26/04	M14S	<b>0.22 <math>\pm</math> 0.04<sup>c</sup></b>	0.04	0.15	6.63

a. The background for U-233/234 is based on the upper 95% coverage 95% confidence tolerance limit of 272 aquifer samples collected within 10 mi of the RWMC. Aquifer background for U-235 is defined as the upper concentration range of 299 aquifer samples collected from 13 monitoring wells within about a 5-mi radius of the RWMC between 1998 and May 2004.

b. RBC = 1E-05 for drinking water. The MCL for uranium (30  $\mu$ g/L) is also applicable, but is applicable as total uranium (30  $\mu$ g/L), not as each individual isotope. None of the RWMC aquifer sample results for total uranium (i.e., 234 + 235 + 238), converted from activity (pCi) to mass ( $\mu$ g), exceeded the MCL.

c. **Black bold font** indicates sample concentrations less than RBCs and/or MCLs, but exceeding aquifer background concentration limits (see Footnote a).

d. A duplicate sample was collected from Well OW-2 12/02/03, and the U-235/236 analysis result did not exceed the aquifer background concentration.

MCL = maximum contaminant level

MDC = minimum detectable concentration

RBC = risk-based concentration

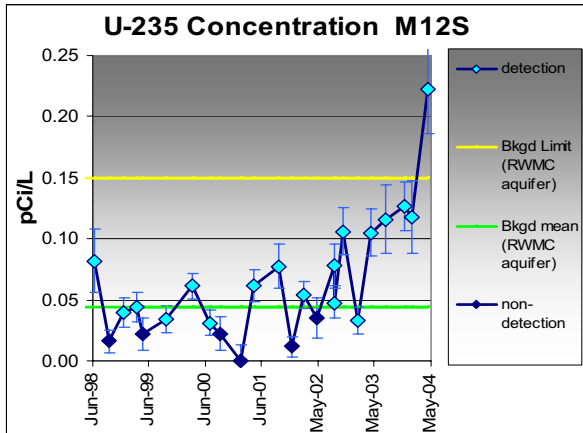


Figure 3-57a. Developing U-235 concentration trend in monitoring Well M12S.

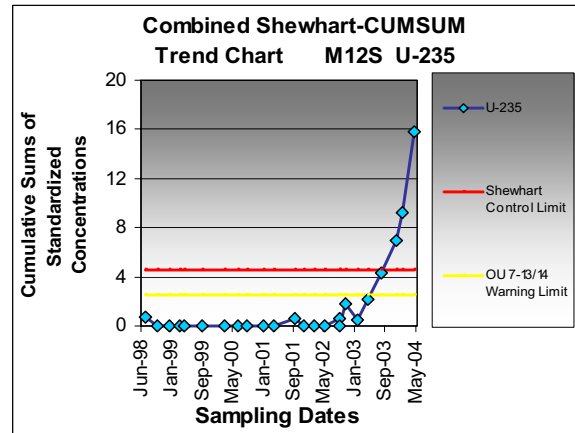


Figure 3-57b. Uranium-235 concentration trend illustrated by statistical control chart method for Well M12S.

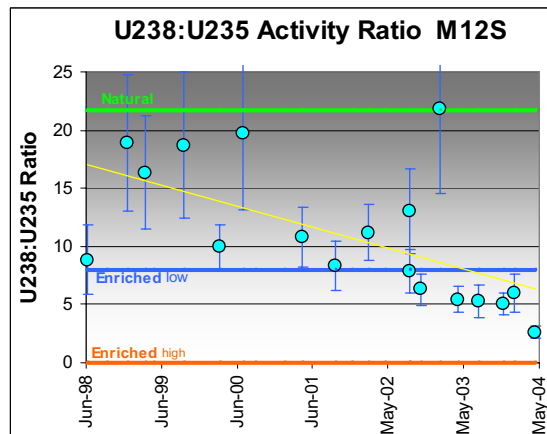


Figure 3-57c. Isotopic ratio trend at Well M12S showing a change from natural uranium to anthropic uranium slightly enriched with U-235.



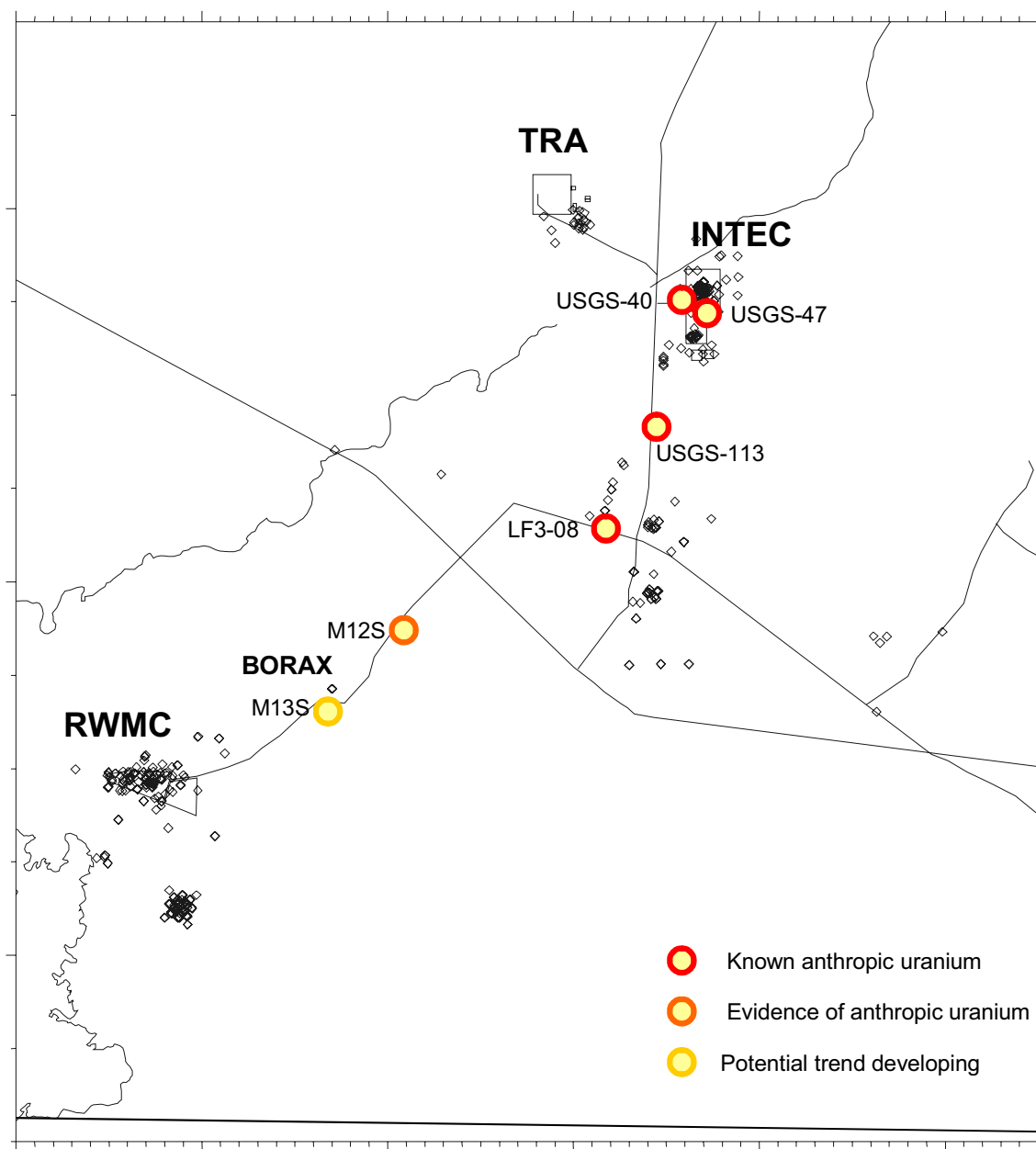


Figure 3-58. Aquifer wells with evidence of low concentrations of anthropogenic uranium at the Idaho National Laboratory.

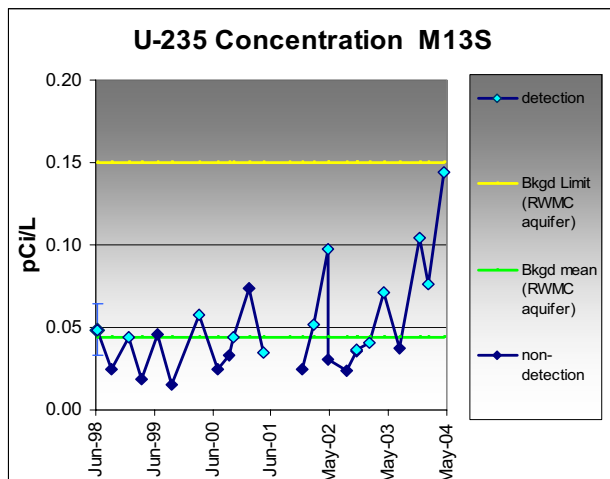


Figure 3-59a. Possible U-235 concentration trend developing in monitoring Well M13S.

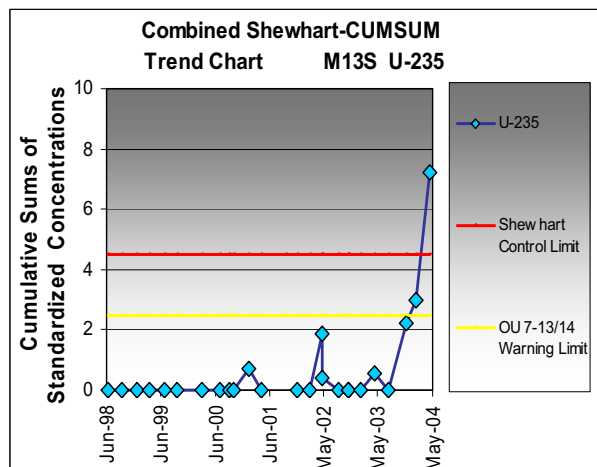


Figure 3-59b. Uranium-235 concentration trend illustrated by statistical control chart method for Well M13S.

Four possible scenarios may explain the increasing concentration of U-235 in Well M12S and possibly Well M13S:

1. An irregularity of natural uranium background in the vicinity.
2. Upgradient sources of anthropic uranium, principally INTEC. Monitoring Well M12S, located about 3.2 km (2 mi) downgradient of INTEC monitoring Well LF3-08, contains very low concentrations of anthropogenic uranium. Uranium-236 and isotopic uranium ratios indicative of anthropogenic sources were measured in Well LF3-08 and three other INTEC monitoring wells (Roback 2002). Figure 3-58 shows the location of monitoring wells containing indications of anthropogenic uranium. Tritium and occasionally C-14 also are detected in Well M12S, however, other signature contaminants unique to INTEC (e.g., chloride, Sr-90, Tc-99, and I-129) are not observed above background. Absence of these signature contaminants does not rule out INTEC as the source of uranium. The signature contaminants may be dispersed and diluted to concentrations at the Well M12S monitoring location that cannot be differentiated from background, or may be below analytical detection limits, or have not yet arrived at the Well M12S location because of chemical or physical deterrents.
3. Increasing concentrations may be due to concentrating effects of decreasing water levels in the eastern SRPA. At first glance, there appears to be a correlation between decreasing water levels and increasing U-235 concentrations at the M12S and M13S locations; however, U-235 is the only uranium isotope that increased in these two wells. Uranium-234 and U-238 concentrations show no change with decreasing water levels. The other monitoring wells around the RWMC also have decreasing water levels, but show no changes in isotopic uranium concentrations. Thus, there does not seem to be a correlation between increasing U-235 concentrations at M12S and M13S and decreasing aquifer levels.
4. Nuclear fuel fragments, fuel residue, and activated metal debris (from the intentional destruction of the Boiling Water Reactor Experiment [BORAX]-I in 1954) are buried at the BORAX-I test site (see Figure 3-58). During cleanup, approximately 12 percent of the fuel was collected and recovered. The remaining 88 percent (3.7 kg) was buried at the BORAX site, some was placed in

the underground reactor shield tank, and some simply covered over with dirt and gravel to reduce radiation levels and prevent the spread of contamination (INL 1996). Rip-rap and a chain link fence were later added to prevent human intrusion. So, there exists a potential for migration of reactor-related contaminants from the BORAX-I burial site. However, the fact that Well M12S is located about 1.2 km (0.75 mi) upgradient of BORAX-I raises some doubt about BORAX being the source of anthropogenic uranium. Tritium and occasionally C-14 are detected in Well M12S; but no other fission or activation products have been observed. Because it is possible that tritium and C-14 are from RTC or INTEC, they are not good indicators of leachates from the BORAX-I burial site. Other wells in the immediate vicinity of BORAX-I (i.e., Wells M11S and EBR-I) exhibit no indications of anthropic uranium, activation or fission products, or influences from upgradient facilities.

Uranium detected in the aquifer in the vicinity of the RWMC is typical of naturally occurring uranium in the aquifer, except for Well M12S and possibly Well M13S. No actions need to be taken on these wells other than continued monitoring, because concentrations are far below regulatory limits. The wide deviation of U-235 concentrations at the Well OW2 location, compared to other RWMC aquifer monitoring locations, is of concern, but cannot be explained at this time. Continued uranium monitoring at downgradient location OW2 is necessary to ascertain whether the wide variations in U-235 concentrations are the start of a trend. A summary of the maximum detected concentrations of U-233/234 and U-238 in aquifer samples since FY 1997 are presented in Tables 3-48 and 3-49, respectively.

#### **3.12.4 Summary of Uranium**

Uranium levels measured in FY 2004 in numerous vadose zone soil-moisture samples significantly exceed local soil-moisture background levels and RBCs for water ingestion. The soil-moisture detections of U-233/234, U-235/236, and U-238 above RBCs are depicted in Figures 3-60, 3-61, and 3-62, respectively. The locations of uranium disposals are based on disposal records. Maximum concentrations detected in soil-moisture and perched water samples are presented in Tables 3-50 and 3-51. Some locations are where multiple detections of uranium correlate with disposal locations, suggesting that uranium might be a potential candidate for model validation or comparison. In the Pad A area, uranium is detected above background levels in all lysimeters above 30 m (100 ft), but has not been measured above background levels at Well I-4D (at 59 m [226.5 ft]). Most interesting is that uranium has been repeatedly detected above background in Well I-4S at the 29.6-m (97-ft) depth (Well I-4S), suggesting that uranium might have migrated to the first B-C interbed, but might not have reached the C-D interbed yet at 67 m (220 ft). Wells D06, PA01, PA02, and TW1 from the Pad A and Pit 5 areas routinely contain elevated uranium concentrations and are indicative of enriched uranium. Uranium concentrations at the west end of the SDA also are significantly above background in Lysimeter Wells 98-5, I-1S, and W23 with concentration and isotopic ratio trends in Well W23; however, no uranium disposals have been recorded in that area. Therefore, the uranium monitoring data cannot be used for comparison to modeling results, which start in the source term with the inventory records; however, the uranium trends in the western end of the SDA highlight some limitations and uncertainties of the inventory records. Uranium detected in the aquifer in the vicinity of the RWMC is typical of naturally occurring uranium in the aquifer, except for Well M12S and possibly Well M13S. No actions need to be taken on these wells other than continued monitoring, because concentrations are far below regulatory limits. The wide deviation of U-235 concentrations at the Well OW2 location, compared to other RWMC aquifer monitoring locations, is of concern, but cannot be explained at this time. Continued uranium monitoring at downgradient-location Well OW2 is necessary to ascertain whether the wide variation in U-235 concentrations are the start of a trend. A summary of the maximum detected concentrations of U-233/234 and U-238 in aquifer samples since FY 1997 are presented in Tables 3-50 and 3-51, respectively.

Table 3-48. Summary of maximum detections of uranium-233/234 in vadose zone soil-moisture and perched water samples at the Radioactive Waste Management Complex from Fiscal Year 1997 through 2004.<sup>a</sup>

Sampling Range (ft bls)	Fiscal Year <sup>b</sup>	Maximum Concentration $\pm 1\sigma$ (pCi/L) <sup>c,d</sup>	Sample Location
Lysimeters 0–35 ft	1997	43 $\pm$ 3	PA03:L33
	1998	60 $\pm$ 4	W23:L08
	1999	57 $\pm$ 4	PA03:L33
	2000	76 $\pm$ 5	W23:L08
	2001	87 $\pm$ 8	W23:L08
	2002	125 $\pm$ 10	W06:L27
	2003	84 $\pm$ 7	W23:L07
	2004	85 $\pm$ 9	W23:L07
Lysimeters 35–140 ft	1997	84 $\pm$ 6	D06:DL02
	1998	97 $\pm$ 7	TW1:DL04
	1999	90 $\pm$ 14	TW1:DL04
	2000	111 $\pm$ 10	D06:DL01
	2001	7.3 $\pm$ 1.3	O3:DL22
	2002	17.3 $\pm$ 1.7	I1S:DL09
	2003	101 $\pm$ 9	TW1:DL04
	2004	121 $\pm$ 10	TW1:DL04
Lysimeters >140 ft	1997	NA	—
	1998	NA	—
	1999	NA	—
	2000	NA	—
	2001	NA	—
	2002	1.9 $\pm$ 0.4	I4D:DL14
	2003	4.7 $\pm$ 0.8	O2D:DL19
	2004	84 $\pm$ 8	TW1:DL03
Perched water wells >140 ft	1997	NA	—
	1998	NA	—
	1999	7.5 $\pm$ 0.6	USGS-92
	2000	6.7 $\pm$ 0.7	USGS-92
	2001	NA	—
	2002	NA	—
	2003	4.4 $\pm$ 0.8	USGS-92
	2004	3.8 $\pm$ 0.8	USGS-92

a. MCL = 30  $\mu$ g/L (total uranium). None of the RWMC aquifer sample results for total uranium (i.e., 234 + 235 + 238), converted from activity (pCi) to mass ( $\mu$ g), exceeded the MCL.

b. Fiscal year spans from October 1 to September 30 (e.g., FY 1997 is October 1, 1996, to September 30, 1997).

c. NA = not analyzed      ND = not detected

d. Local soil-moisture background for U-233/234 is currently 2.1 pCi/L, with an upper concentration guideline of 3.5 pCi/L, based on soil-moisture samples collected outside the SDA.

MCL = maximum contaminant level

SDA = Subsurface Disposal Area

Table 3-49. Summary of maximum detections of uranium-238 in vadose zone soil-moisture and perched water samples at the Radioactive Waste Management Complex from Fiscal Year 1997 through 2004.<sup>a</sup>

Sampling Range (ft bls)	Fiscal Year <sup>b</sup>	Maximum Concentration $\pm 1\sigma$ (pCi/L) <sup>c,d</sup>	Sample Location
Lysimeters 0–35 ft	1997	34 $\pm$ 3	PA03:L33
	1998	40 $\pm$ 3	PA03:L33
	1999	41 $\pm$ 3	PA03:L33
	2000	46 $\pm$ 3	W23:L08
	2001	53 $\pm$ 5	W23:L08
	2002	53 $\pm$ 4	W06:L27
	2003	54 $\pm$ 5	W23:L07
	2004	51 $\pm$ 6	W23:L07
Lysimeters 35–140 ft	1997	49 $\pm$ 4	D06:DL02
	1998	49 $\pm$ 4	D06:DL02
	1999	49 $\pm$ 3	D06:DL01
	2000	53 $\pm$ 5	D06:DL01
	2001	4.7 $\pm$ 1.0	O3:DL22
	2002	9.4 $\pm$ 1.1	I1S:DL09
	2003	45 $\pm$ 5	D06:DL01
	2004	48 $\pm$ 5	D06:DL02
Lysimeters >140 ft	1997	NA	—
	1998	NA	—
	1999	NA	—
	2000	NA	—
	2001	NA	—
	2002	NA	—
	2003	3.0 $\pm$ 0.6	O2:DL19
	2004	8.7 $\pm$ 1.3	TW1:DL03
Perched water wells >140 ft	1997	NA	—
	1998	3.6 $\pm$ 1.1	USGS-92
	1999	4.7 $\pm$ 0.4	USGS-92
	2000	3.2 $\pm$ 0.4	USGS-92
	2001	NA	—
	2002	NA	—
	2003	3.7 $\pm$ 0.7	USGS-92
	2004	3.3 $\pm$ 0.8	88-02D

a. MCL = 30  $\mu\text{g/L}$  (total uranium). None of the RWMC aquifer sample results for total uranium (i.e., 234 + 235 + 238), converted from activity (pCi) to mass ( $\mu\text{g}$ ), exceeded the MCL.

b. Fiscal year spans from October 1 to September 30 (e.g., FY 1997 is October 1, 1996, to September 30, 1997).

c. NA = not analyzed      ND = not detected

d. Local soil-moisture background for U-238 is currently 1.1 pCi/L, with an upper concentration guideline of 2.0 pCi/L, based on soil-moisture samples collected outside the SDA.

MCL = maximum contaminant level

SDA = Subsurface Disposal Area

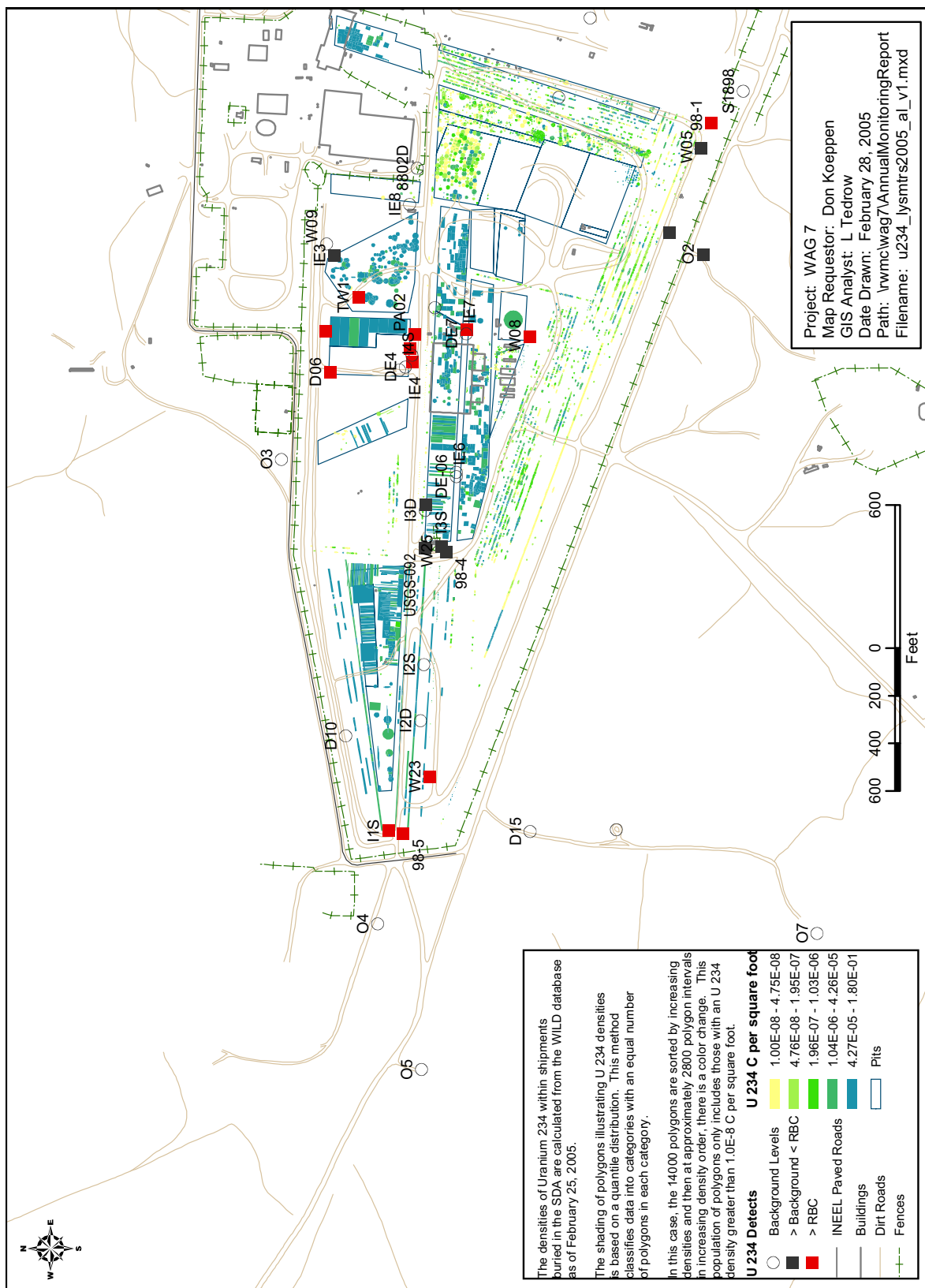


Figure 3-60. Disposal locations, vadose zone detection locations, and densities for U-233/234 at the Subsurface Disposal Area.

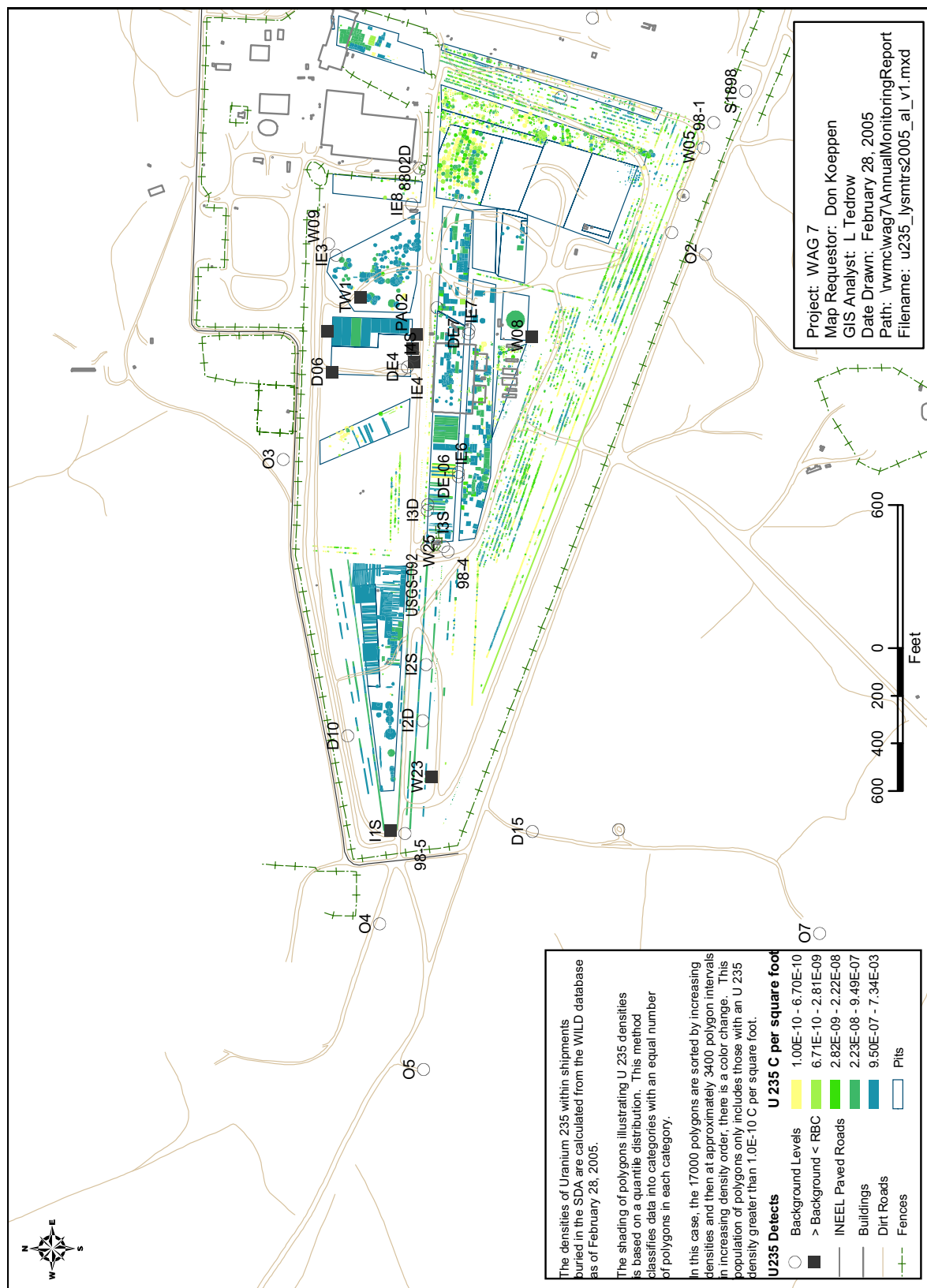


Figure 3-61. Disposal locations, vadose zone detection locations, and densities for uranium-235/236 at the Subsurface Disposal Area.



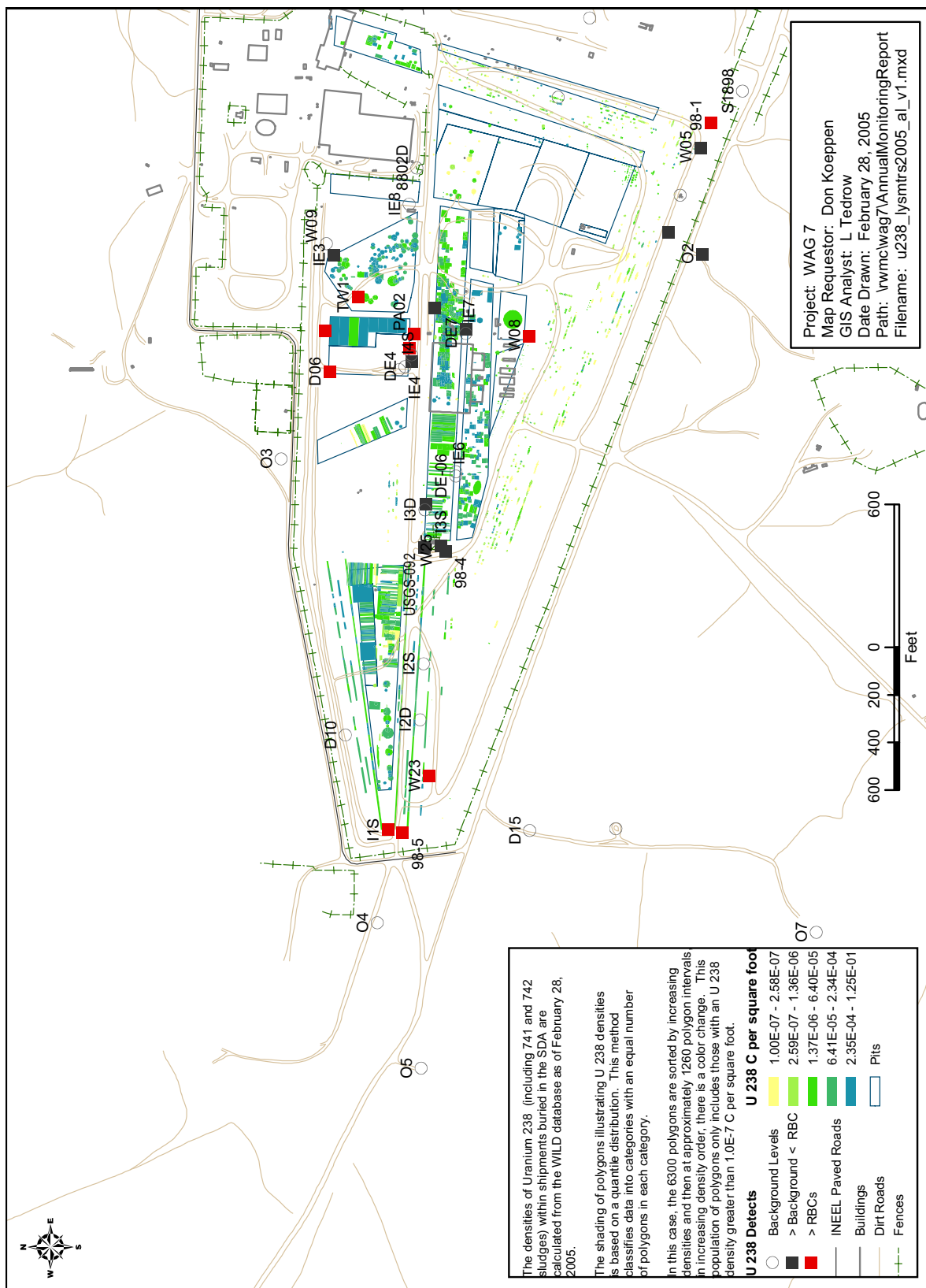


Figure 3-62. Disposal locations, vadose zone detection locations, and densities for uranium-238 at the Subsurface Disposal Area.



Table 3-50. Summary of maximum detected concentrations of uranium-233/234 from aquifer wells in the vicinity of the Radioactive Waste Management Complex since Fiscal Year 1997.<sup>a</sup>

Fiscal Year <sup>b</sup>	Maximum Concentration $\pm$ 1 $\sigma$ (pCi/L)	Well Location
1997	NA <sup>c</sup>	—
1998	1.65 $\pm$ 0.16	M3S
1999	1.54 $\pm$ 0.13	M12S
2000	1.6 $\pm$ 0.2	M14S
2001	4.3 $\pm$ 0.4	M14S
2002	1.68 $\pm$ 0.14	M4D
2003	2.01 $\pm$ 0.18	OW-2
2004	2.08 $\pm$ 0.18	OW-2

a. MCL = 30  $\mu$ g/L (total uranium). None of the RWMC aquifer sample results for total uranium (i.e., 234 + 235 + 238), converted from activity (pCi) to mass ( $\mu$ g), exceeded the MCL.

b. Fiscal year spans from October 1 to September 30 (e.g., FY 1997 is October 1, 1996, to September 30, 1997).

c. No samples were analyzed for U-233/234.

FY = fiscal year

MCL = maximum contaminant level

RWMC = Radioactive Waste Management Complex

Table 3-51. Summary of maximum detected concentrations of uranium-238 from aquifer wells in the vicinity of the Radioactive Waste Management Complex since Fiscal Year 1997.<sup>a</sup>

Fiscal Year <sup>b</sup>	Maximum Concentration $\pm$ 1 $\sigma$ (pCi/L)	Well Location
1997	NA <sup>c</sup>	—
1998	0.74 $\pm$ 0.08	M7S
1999	0.75 $\pm$ 0.07	M12S
2000	0.72 $\pm$ 0.11	M3S
2001	2.1 $\pm$ 0.2	M14S
2002	0.78 $\pm$ 0.08	M4D
2003	0.90 $\pm$ 0.10	A11A31
2004	0.90 $\pm$ 0.09	OW2

a. MCL = 30  $\mu$ g/L (total uranium). None of the RWMC aquifer sample results for total uranium (i.e., 234 + 235 + 238), converted from activity (pCi) to mass ( $\mu$ g), exceeded the MCL.

b. Fiscal year spans from October 1 to September 30 (e.g., FY 1997 is October 1, 1996, to September 30, 1997).

c. No samples were analyzed for U-238.

FY = fiscal year

MCL = maximum contaminant level

RWMC = Radioactive Waste Management Complex

### 3.13 Other Radionuclide Contaminants

All waste zone, vadose zone, and aquifer samples were analyzed for 13 or more gamma-emitting radionuclides, resulting in only one detection. A positive detection of Cs-137 was reported in a sample collected from Lysimeter IE4:DL32 the first quarter of 2004. The measured concentration was 105  $\pm$  12 pCi/L. No Cs-137 was detected in subsequent quarters from the same lysimeter.



## 4. ORGANIC CONTAMINANTS

Carbon tetrachloride ( $\text{CCl}_4$ ), tetrachloroethene (PCE), and methylene chloride have been identified as COPCs, primarily for the groundwater ingestion exposure pathway for OU 7-13/14. This section presents sampling results for those COPCs followed by sampling results for other organic compounds detected during monitoring.

### 4.1 Carbon Tetrachloride

The primary source of  $\text{CCl}_4$  at the SDA is Series 743 waste drums shipped from RFP between 1966 and 1970 (Miller and Varvel 2005). Initially, 9,689 Series 743 waste drums were buried in multiple pits in the SDA, including Pits 4, 5, 6, 9, 10, 11, and 12. In the 1970s, all 1,015 drums from Pits 11 and 12 were retrieved, leaving 8,674 drums of Series 743 waste drums in the SDA. The estimated mass of  $\text{CCl}_4$  contained in these 8,674 drums is  $7.9\text{E}+05$  kg (Miller and Varvel 2005).

Carbon tetrachloride has been detected at the SDA in surficial sediments, vadose zone soil gas, vadose zone soil water (perched water and lysimeters), and the aquifer beneath and surrounding the SDA. Carbon tetrachloride vapor also has been detected emanating from the soil surface by surface isolation flux chambers.

#### 4.1.1 Waste Zone

Carbon tetrachloride was detected in high concentrations in soil-gas samples collected from vapor probes placed in the waste in Pits 4 and 10. The samples were collected in Tedlar bags or SUMMA canisters using a glovebox and analyzed with an INNOVA Model 1314 photoacoustic multigas analyzer. Some of the field duplicate samples also were analyzed using standard laboratory gas chromatography and mass spectrometry (GC/MS) as an accuracy check on the INNOVA results.

In FY 2004, the probes were sampled quarterly and 10–13 probes produced a sample each quarter. Carbon tetrachloride was detected in all of the probes that yielded a sample. Table 4-1 presents results for  $\text{CCl}_4$  and other VOCs for which analysis was performed. The maximum  $\text{CCl}_4$  concentration measured was 79,600 ppmv at the 743-08-VP2 probe (4.1 m [13.4 ft] bls) in February 2004. The  $\text{CCl}_4$  concentrations at this location are routinely greater than 30,000 ppmv, which is near the predicted equilibrium vapor concentration of  $\text{CCl}_4$  in Series 743 sludge (46,000 at  $10^\circ\text{C}$ ) and close to the pure component equilibrium gas-concentration value (71,000 at  $10^\circ\text{C}$ ). This is indicative of relatively “fresh” Series 743 sludge or liquid-phase VOCs.

During the last two quarters of FY 2003, a divergence was detected in waste zone soil-gas sampling results between the INNOVA and the duplicate analyses performed using GC/MS. Until that time, there was good agreement (less than 10 percent) between the INNOVA and the GC/MS. The INNOVA was sent back for recalibration several times, but the discrepancy could not be resolved. Since that time, INNOVA results for  $\text{CCl}_4$  have been from 20 percent to several times greater than the GC/MS results. This appears to be true for the FY 2004 results as well. This is unusual because the INNOVA is consistently lower than the standard gas concentrations. A plan for resolving the problem is being developed that includes an evaluation of the standard gases and all other sampling and analysis procedures.

Waste zone soil-moisture samples were not analyzed for VOCs in FY 2004 because of limited sample volumes and analytical priorities.

Table 4-1. Volatile organic compound vapor concentration results from Subsurface Disposal Area vapor probes in FY 2004.<sup>a</sup>

Probe	Port Depth (ft)	Date Sampled	Sample No.	Carbon Tetrachloride (ppmv)	Chloroform (ppmv)	1,1,1-TCA (ppmv)	TCE (ppmv)	PCE (ppmv)
743-03-VP1	19	11/11/03	IPV30701VA	272	49	15	75	15
		9/27/04	IPV35501VA	25 <sup>b</sup>	3 <sup>b</sup>	4 <sup>b</sup>	13 <sup>c</sup>	9 <sup>b</sup>
743-03-VP2	14	11/11/03	IPV30801VA	116	22	8	33	11
		5/27/04	IPV34001VA	50,100	5,370	1,650	656	218
		9/27/04	IPV35601VA	5,940	5,670	1,900	694	297
743-03-VP3	5	11/11/03	IPV30901VA	275	90	16	24	7
		2/17/04	IPV32501VA	5,970	861	274	1,090	1,120
		5/26/04	IPV34101VA	9,120	1,950	763	1,440	601
743-08-VP1	21	11/11/03	IPV31001VA	14,800	8,190	627	2,180	131
		2/17/04	IPV32601VA	73,100	13,900	1,340	4,970	3,680 <sup>c</sup>
		5/27/04	IPV34201VA	68,300	14,300	1,630	7,480	612
		5/27/04	IPV34201HU <sup>d</sup>	48,000	15,000	1,500	11,000	<150
		9/27/04	IPV35801VA	53,900	13,400	1,370	6,910	395
		9/27/04	IPV358013A <sup>d</sup>	38,000	17,000 <sup>c</sup>	1,700	13,000 <sup>c</sup>	140
743-08-VP2	14	11/11/03	IPV31101VA	502	210	20	38	1
		2/17/04	IPV32701VA	79,600 <sup>c</sup>	12,100	1,340	4,040	2,630
		2/17/04	IPV32701VT <sup>d</sup>	5,200	1,600	3,400	8,700	2,300
		5/27/04	IPV34301VA	55,700	10,100	1,220	3,260	356
		5/27/04	IPV34301HU <sup>d</sup>	44,000	12,000	1,400	11,000	150
		9/27/04	IPV35901VA	61,900	10,600	1,300	3,720	373
743-08-VP3	6	11/11/03	IPV31201VA	951	362	34	88	6
		2/17/04	IPV32801VA	25,700	5,560	590	2,330	1,650
		5/27/04	IPV34401VA	12,000	4,700	386	2,710	104
		9/27/04	IPV36001VA	17,400	4,570	472	1,790	108
743-18-VP1	21	5/27/04	IPV34501VA	144 <sup>b</sup>	57 <sup>b</sup>	6 <sup>b</sup>	90 <sup>b</sup>	8 <sup>b</sup>
		9/27/04	IPV36101VA	263 <sup>b</sup>	80 <sup>b</sup>	8 <sup>b</sup>	64 <sup>b</sup>	4 <sup>b</sup>
743-18-VP3	8	11/11/03	IPV31401VA	70	39	16	101	30
		2/17/04	IPV33001VA	18,000	3,770	468	1,660	1,140
		5/27/04	IPV34601VA	1,640	518	74	415	17
		9/27/04	IPV36201VA	3,190	673	127	395	20
743-18-VP4	15	11/11/03	IPV31501VA	8,220	1,200	283	1,400	40
		11/11/03	IPV31501VT <sup>d</sup>	620	100	39	130	18
		2/17/04	IPV33101VA	8,430	1,350	278	1,720	-6 <sup>c</sup>
		5/27/04	IPV34701VA	7,400	973	195	1,340	5
		9/27/04	IPV36301VA	9,730	1,340	266	1,490	12

Table 4-1. (continued).

Probe	Port Depth (ft)	Date Sampled	Sample No.	Carbon Tetrachloride (ppmv)	Chloroform (ppmv)	1,1,1-TCA (ppmv)	TCE (ppmv)	PCE (ppmv)
DU-08-VP2	16	11/10/03	IPV30001VA	10,900	7,280	<b>3,810<sup>c</sup></b>	6,770	741
		2/17/04	IPV31601VT <sup>d</sup>	23,000	5,700	700	1,500	61
		5/26/04	IPV33201VA	17,000	5,720	3,050	5,700	1,980
		5/26/04	IPV33201HU <sup>d</sup>	2,300	700	1,600	3,600	650
		9/27/04	IPV34801VA	1,500	4,630	2,710	5,680	1,670
DU-10-VP2	11	11/10/03	IPV30201VA	4,510	1,730	2,030	3,390	1,360
		2/17/04	IPV31801VA	3,530	1,390	1,310	2,860	1,280
		5/26/04	IPV33401VA	4,560	1,270	1,270	2,380	1,260
		5/26/04	IPV33401HU <sup>d</sup>	1,300	220	540	750	140
		9/27/04	IPV35001VA	4,930	1,350	1,440	2,750	1,320
		9/27/04	IPV350013A <sup>d</sup>	2,700	780	1,700	3,800	1,800
DU-10-VP3	7	11/10/03	IPV30301VA	7,000	1,240	1,850	2,370	1,560
		2/17/04	IPV31901VA	3,910	797	1,095	1,760	1,080
		5/26/04	IPV33501VA	6,660	1,050	1,400	1,980	1,530
		9/27/04	IPV35101VA	8,060	1,540	1,700	2,680	1,790
DU-14-VP2	12	11/10/03	IPV30501VA	6,700	5,140	1,530	9,980	-382
		11/10/03	IPV30501VT <sup>d</sup>	2,800	1,800	1,300	6,800	250
		2/17/04	IPV32101VA	6,910	2,740	1,060	5,890	761
		5/26/04	IPV33701VA	11,400	3,300	1,170	6,810	915
		9/27/04	IPV35301VA	13,900	3,630	1,280	7,760	1,010
DU-14-VP3	5	11/10/03	IPV30601VA	699	515	312	703	273
		2/17/04	IPV32201VA	946	557	301	1,750	365
		5/26/04	IPV33801VA	2,250	946	519	2,030	446
		9/27/04	IPV35401VA	2,200	868	398	2,060	418

a. All analyses were performed with the INNOVA gas analyzer except where noted. The INL ECL analyses were performed with GC/MS.

b. Low sample volume, results unreliable.

c. **Bold font** indicates maximum measured concentration.

d. Duplicate samples in 250-mL SUMMA canisters analyzed using GC/MS by INL ECL.

e. Negative results are considered undetected.

GC/MS = gas chromatography and mass spectrometry

INL ECL = Idaho National Laboratory Environmental Chemistry Laboratory

PCE = tetrachloroethene

TCA = 1,1,1-trichloroethane

TCE = trichloroethene

## 4.1.2 Vadose Zone

**4.1.2.1 Perched Water and Lysimeter.** Vadose zone soil-moisture samples collected by WAG 7 were not analyzed for VOCs in FY 2004 because of limited sample volumes and analytical priorities. Samples collected by WAG 7 have not been analyzed for VOCs since September 2000.

Personnel from the USGS attempted to collect a perched water sample from Well USGS-92 in April 2004, but insufficient water was available for a sample. A perched water sample was obtained in May 2004 from Well USGS-92, but it was not analyzed for organics. Figure 4-1 shows the history of the CCl<sub>4</sub> concentrations in perched water in Well USGS-92. The decline in CCl<sub>4</sub> concentrations in Well USGS-92 since 1997 is attributed to operation of the OCVZ vapor vacuum extraction with treatment

(VVET) system, which began in January 1996. Well USGS-92 is located near vapor vacuum extraction Well 7V.

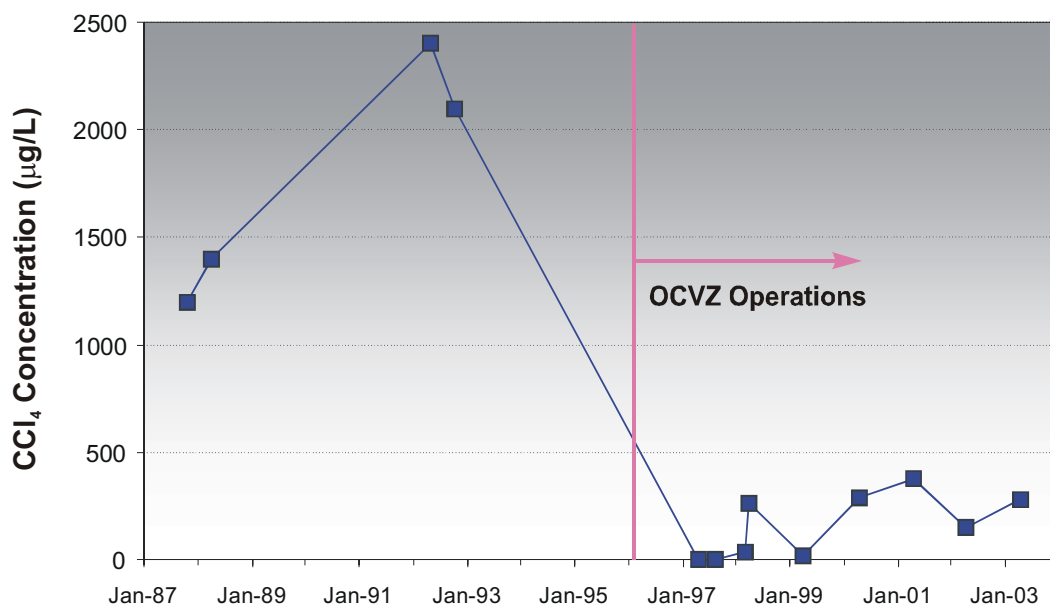


Figure 4-1. History of carbon tetrachloride concentration in perched water in Well USGS-92.

**4.1.2.2 Soil Gas.** Soil-gas monitoring in the vadose zone is accomplished using an extensive system of permanent soil-gas sampling ports inside and outside of the SDA boundary. The ports are made of stainless-steel tubing attached to the outside of well casings. The bottoms of the tubes are perforated and surrounded by sand. Figures 4-2a and 4-2b show the location of wells with soil-gas sampling ports in the vicinity of the SDA and the depths of the ports. The port depths range from a minimum depth of 4.6 m (15 ft) in Well WWW-1 to a maximum depth of 180 m (591 ft), just above the water table in Well M13S.

Over 1,800 vadose zone soil-gas samples were collected in FY 2004 and analyzed with a Brüel and Kjær photoacoustic multigas analyzer. Figure 4-3 shows the detection frequencies of CCl<sub>4</sub> for all samples. Nearly one-half of all detections were less than 10 ppmv, and 46 detections were greater than 1,000 ppmv. The complete set of soil-gas data for FY 2004 can be found in three reports:

- *Environmental and Operational End-Year Data Report for the OU 7-08 Organic Contamination in the Vadose Zone Project—2003* (Housley 2004)
- *Environmental and Operational Mid-Year Data Report for the OU 7-08 Organic Contamination in the Vadose Zone Project—2004* (Housley and Sondrup 2004)
- *Environmental and Operational End-Year Data Report for the OU 7-08 Organic Contamination in the Vadose Zone Project—2004* (Housley 2005).

The maximum CCl<sub>4</sub> concentration measured in FY 2004 was 4,030 ppmv in Well 8902, Port 6, at a depth of 23.7 m (78 ft) on February 3, 2004. This is approaching the highest concentration measured in vadose zone monitoring wells, which was 4,864 ppmv in nearby Well 9302, Port 6, at a depth of 23.5 m (77 ft) in January 1995. The highest levels of CCl<sub>4</sub> are located in the central portion of the SDA between Pits 4, 5, 6, and 10 and decrease with distance away from this area. Concentrations in the wells farthest from the SDA, OCVZ-11, and OCVZ-13 are less than 1 ppmv.

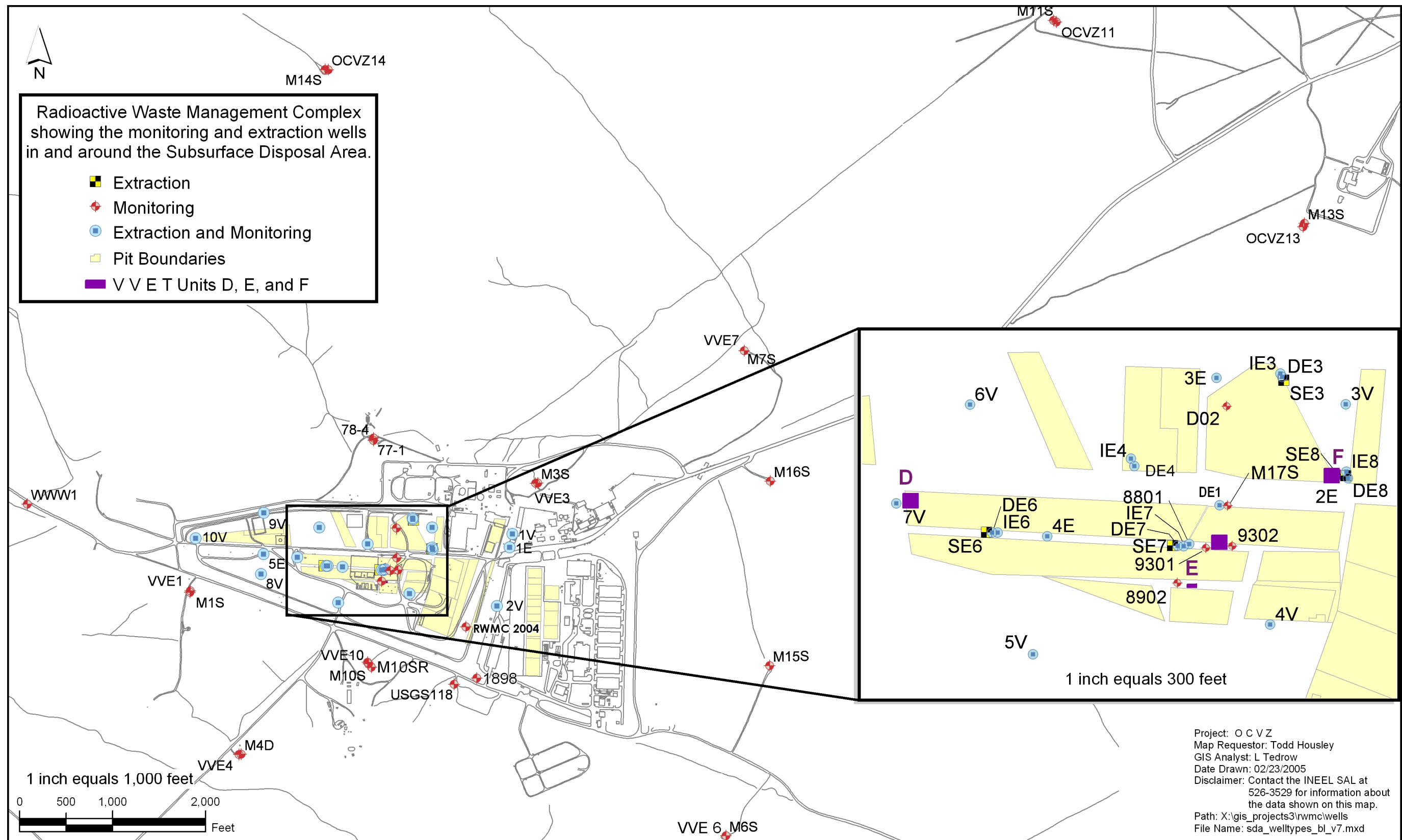


Figure 4-2a. Location of soil-gas sampling and extraction wells in the vicinity of the Radioactive Waste Management Complex.

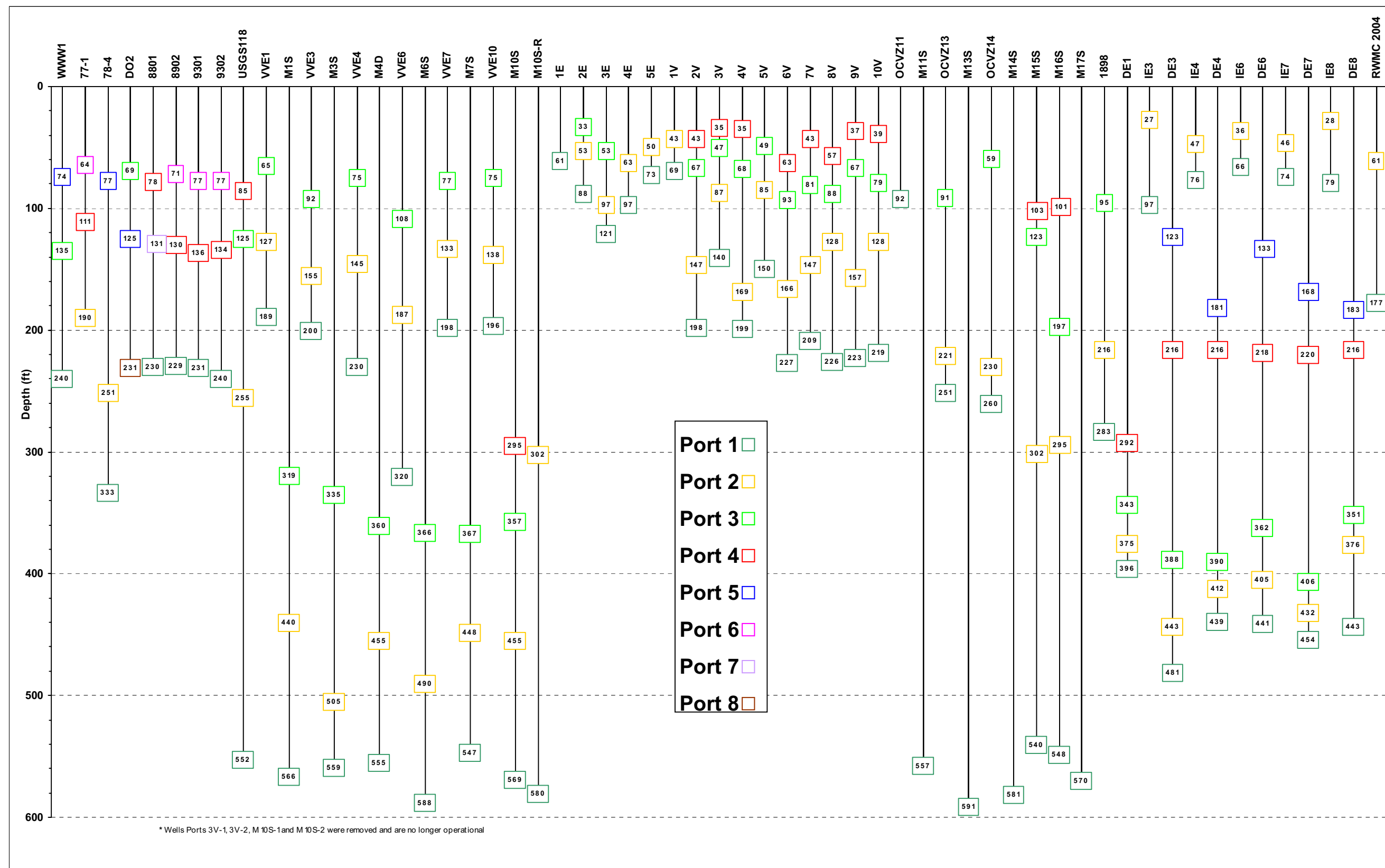


Figure 4-2b. Depth of the sampling ports in wells in the vicinity of the Radioactive Waste Management Complex.



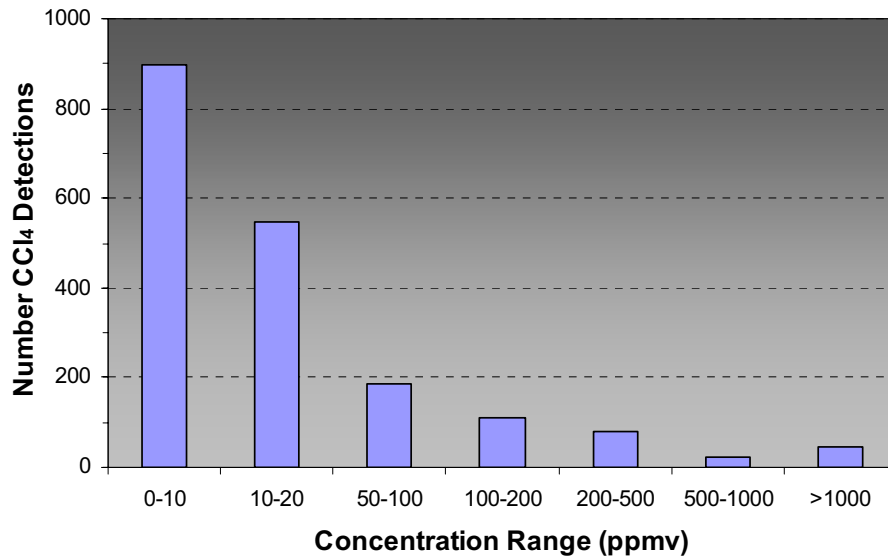


Figure 4-3. Histogram showing the detection frequencies of carbon tetrachloride in vadose zone soil gas samples collected during FY 2004 in the vicinity of the Radioactive Waste Management Complex.

Vertically, the CCl<sub>4</sub> soil-gas contamination extends from land surface down to the water table. Currently, in the center of the SDA, the CCl<sub>4</sub> concentrations can be 1,000 ppmv or higher above the B-C interbed. Concentrations then decrease sharply across the B-C interbed down to a few hundred ppmv. Below the C-D interbed, concentrations are generally less than 50 ppmv. However, it appears that when the VVET systems are extracting from the deep extraction wells, the maximum concentrations are reduced to approximately 20 ppmv or less.

Overall, the organic vapor concentrations at most locations are much less now than before full-time operation of the OCVZ VVET system began in January 1996. Figures 4-4 and 4-5 show the soil-gas concentrations at two wells (8801 and 9301) near vapor extraction Well 8901D. In 1993, a treatability study was performed and soil-gas extraction from Well 8901D was performed for approximately 3 months. This event had little lasting impact on the concentration levels. Before 1996, the CCl<sub>4</sub> concentration at about 23.5 m (77 ft) deep (above the B-C interbed) was approximately 3,000 ppmv in these two wells. However, after full-time extraction began in January 1996, the concentration dropped to about 1,000 ppmv. Near the 40-m (130-ft) depth below the B-C interbed, the concentration dropped from about 600 ppmv before vapor vacuum extraction operations to 100 ppmv after operations. Concentrations in the deeper ports, around 70 m (230 ft), appear to be unchanged by operations. In Well 9V (see Figure 4-6), the initial drop in concentration was not so dramatic, probably because it is located farther from an extraction well; however, the decrease has been steady. Even the deep gas port at 68 m (223 ft) shows a clear decline in concentrations.

In FY 2004, vadose zone soil-gas concentrations at several locations showed an overall increase over FY 2003 levels. The increase in FY 2004 is the result of VVET Units A and B being shut down for an extended period of time before being replaced with Units E and F, respectively. Unit B ceased operation in February 2003, and replacement Unit F was started briefly, nearly a year later, in January 2004, and did not begin full-scale operations until March 2004. Unit A was shut down in September 2003, and replacement Unit E was started in April 2004. During the time Unit B and especially Unit A were down, the concentrations in nearby monitoring wells (e.g., 8801, DO2, 9301, 9302, IE7, IE8, 2E) increased dramatically. Soon after starting Unit E, however, the concentrations in those wells decreased just as dramatically. This can be seen in Figures 4-4, 4-5, and to a lesser degree, in Figure 4-6.

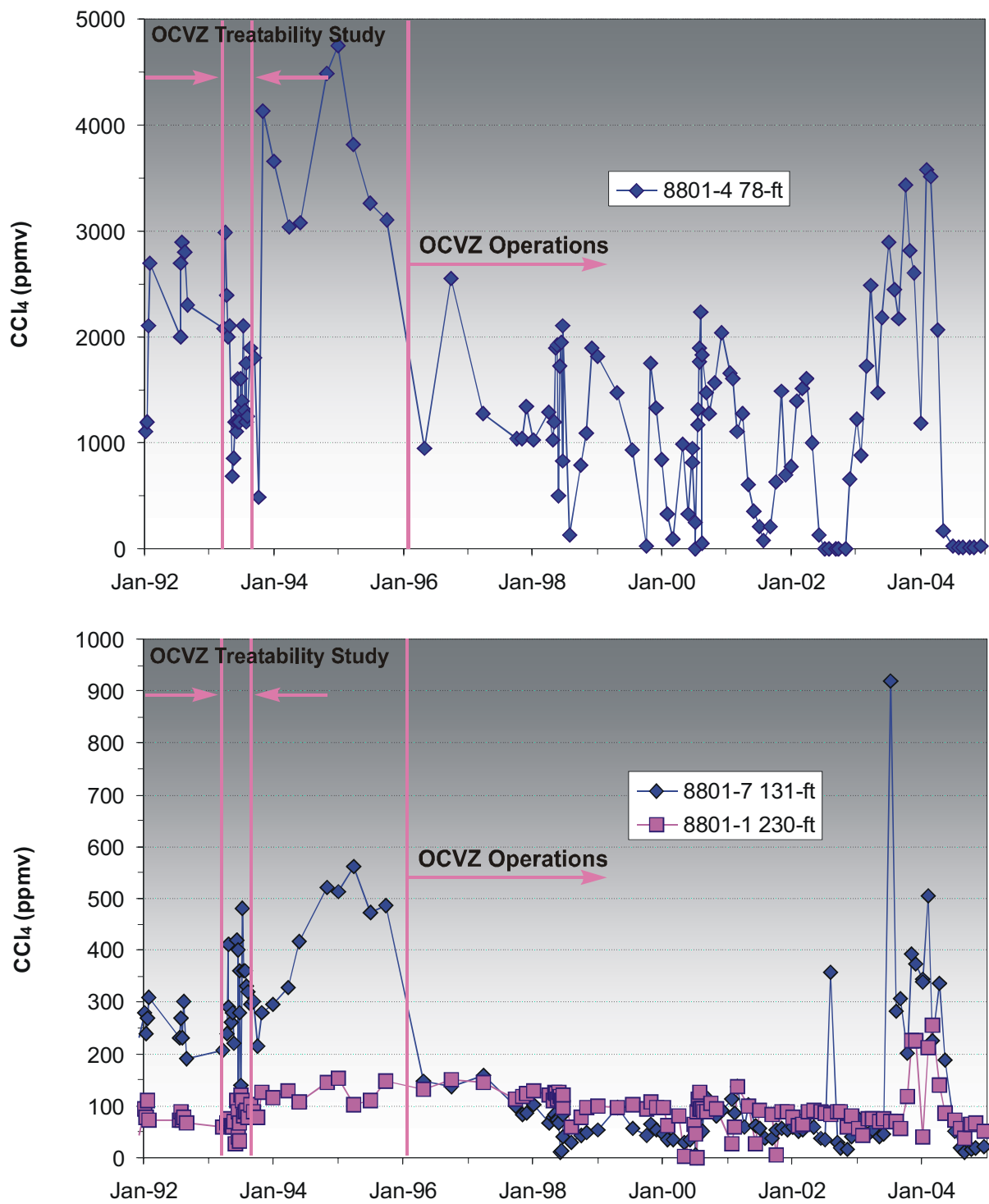


Figure 4-4. Carbon tetrachloride soil-gas concentration time history for selected ports in Well 8801.

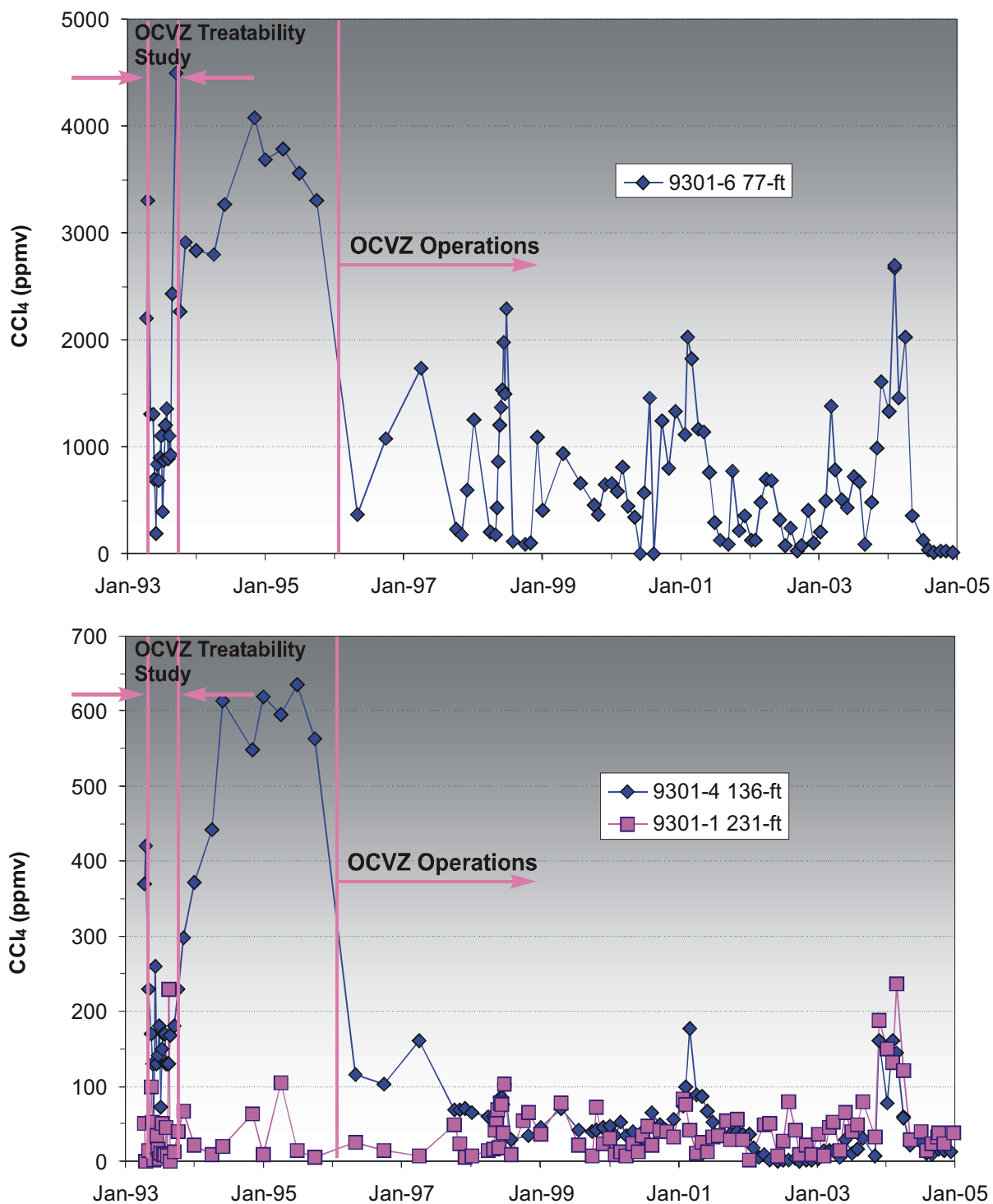


Figure 4-5. Carbon tetrachloride soil-gas concentration time history for selected ports in Well 9301.

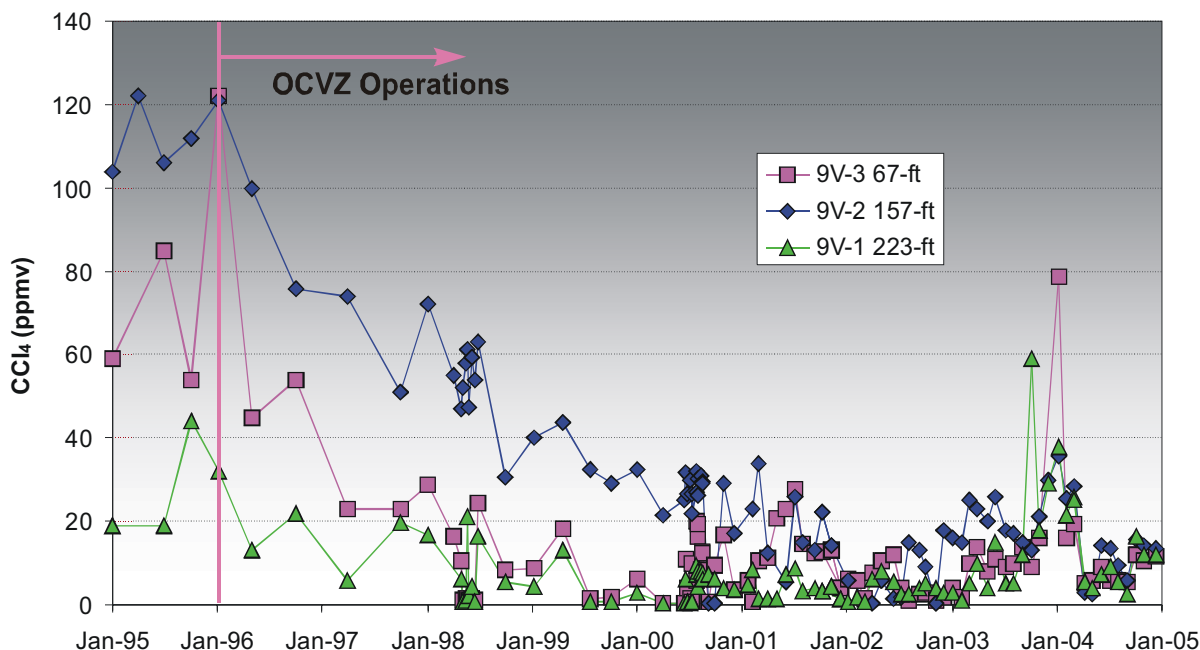


Figure 4-6. Carbon tetrachloride soil-gas concentration time history for selected ports in Well 9V.

#### 4.1.3 Aquifer

Sixty-eight aquifer samples were collected in FY 2004 from 21 monitoring wells in the vicinity of the RWMC and analyzed for VOCs. Forty-seven of the samples were collected by WAG 7 personnel from 15 monitoring wells and analyzed for CCl<sub>4</sub>. Twenty-nine of those 47 samples (i.e., 62 percent) had detections above the quantitation limit of 1 µg/L. Of those 29 detections, two (i.e., 7 percent) exceeded the primary drinking water MCL of 5 µg/L. This is down from 21 percent (seven out of 33) in FY 2003. Samples collected by WAG 7 were collected in December 2003, January 2004, and April/May 2004 from monitoring Wells AllA31, M1S, M3S, M4D, M6S, M7S, M11S, M12S, M13S, M14S, M15S, M16S, M17S, OW2, and USGS-127. No sampling was conducted in the fourth quarter of FY 2004 because of a switch to semiannual sampling, which began after the third quarter sampling was complete. The WAG 7 aquifer sampling results above the quantitation limit are Summarized in Table 4-2.

The USGS collected 19 of the 68 aquifer samples from six aquifer wells in the vicinity of the RWMC. Fifteen of the 19 samples (i.e., 79 percent) had detections greater than or equal to the minimum reporting level of 0.2 µg/L. Of the 15 detections, eleven (i.e., 73 percent) met or exceeded the primary drinking water MCL of 5 µg/L. This is up from 44 percent in FY 2003. All eleven samples that exceeded the MCL were taken from the RWMC Production Well. Only the sample taken in March 2004 did not exceed the MCL. Monthly samples were collected by the USGS from the RWMC Production Well. Samples were collected in October 2003 from Wells USGS-87, USGS-89, and USGS-120. Samples were collected in April 2004 from wells USGS-87, USGS-89, USGS-117, and USGS-119. The USGS sample results greater than or equal to the minimum reporting level are also summarized in Table 4-2. Volatile organic compound data from the USGS could only be obtained through August 2004. The September sample from the RWMC Production Well was not included in this discussion.

Table 4-2. Carbon tetrachloride results above quantitation limit (Waste Area Group 7 results) or minimum reporting level in the aquifer (USGS results) in the vicinity of the Radioactive Waste Management Complex.

Well	Sample Date	Sample Concentration (µg/L)	Quantitation Limit or Minimum Reporting Level (µg/L)
Waste Area Group 7 Monitoring Results			
M14S	12/01/03	0.95 <sup>a</sup>	1.0
M16S	12/01/03	4.3	1.0
M6S	12/01/03	2.1	1.0
M7S	12/01/03	4.5	1.0
A11A31	12/02/03	4.5	1.0
M3S	12/02/03	2.1	1.0
OW2	12/02/03	0.46 <sup>a</sup>	1.0
OW2	12/02/03	0.47 <sup>a</sup>	1.0
M15S	12/03/03	1.9	1.0
M17S	12/03/03	1.8	1.0
A11A31	01/20/04	4.9	1.0
M6S	01/20/04	2	1.0
M7S	01/20/04	5.2 <sup>b</sup>	1.0
M16S	01/21/04	4.4	1.0
M17S	01/21/04	1.7	1.0
M14S	01/26/04	0.86 <sup>a</sup>	1.0
OW2	01/26/04	0.46 <sup>a</sup>	1.0
OW2	01/26/04	0.41 <sup>a</sup>	1.0
M15S	01/27/04	1.8	1.0
M3S	01/27/04	2.2	1.0
A11A31	04/26/04	3.4	1.0
M14S	04/26/04	0.9 <sup>a</sup>	1.0
M3S	04/27/04	2.5	1.0
M6S	05/03/04	2.8	1.0
OW2	05/03/04	0.81 <sup>a</sup>	1.0
M15S	05/04/04	1.9	1.0
M16S	05/04/04	4.2	1.0
M16S	05/04/04	4.3	1.0
M7S	05/05/04	6.1 <sup>b</sup>	1.0
United States Geological Survey Monitoring Results			
RWMC Production	10/09/03	5.4 <sup>b</sup>	0.2
	11/13/03	6 <sup>b</sup>	0.2
	12/18/03	6.8 <sup>b</sup>	0.2
	01/15/04	6.3 <sup>b</sup>	0.2
	01/15/04	6.3 <sup>b</sup>	0.2
	02/12/04	6.2 <sup>b</sup>	0.2
	03/11/04	4.9	0.2
	04/08/04	6.2 <sup>b</sup>	0.2
	05/12/04	6 <sup>b</sup>	0.2

Table 4-2. (continued).

Well	Sample Date	Sample Concentration (µg/L)	Quantitation Limit or Minimum Reporting Level (µg/L)
RWMC Production	06/10/04	5.4 <sup>b</sup>	0.2
	07/08/04	5.5 <sup>b</sup>	0.2
	08/12/04	6 <sup>b</sup>	0.2
USGS-087	10/09/03	3.3	0.2
USGS-087	04/08/04	3.3	0.2
USGS-089	10/02/03	<0.2	0.2
USGS-089	04/13/04	<0.2	0.2
USGS-117	04/07/04	<0.2	0.2
USGS-119	04/07/04	<0.2	0.2
USGS-120	10/09/03	3.0	0.2

a. Concentrations with a “J” subscript were positively identified in the sample and assigned a “J” data qualifier flag. The qualifier flag was assigned because the recovery of one of the surrogates was slightly above the upper control limit. The reported concentrations might not be an accurate representation of the amount actually present in the sample and should only be used as estimated quantities.

b. **Red bold font** indicates sample concentrations that exceed the MCL.

MCL = maximum contaminant level

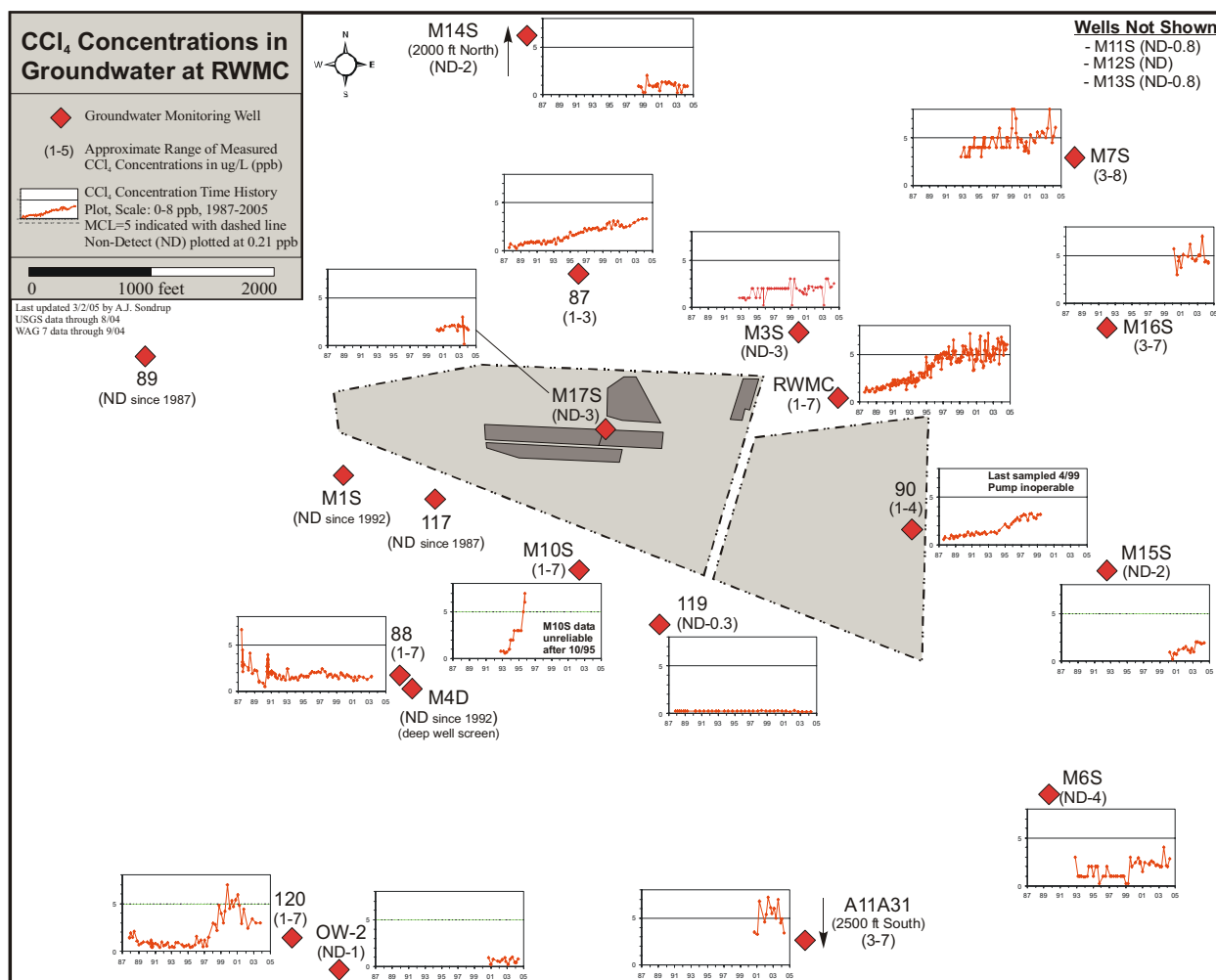
When FY 2004 WAG 7 and USGS results are combined, CCl<sub>4</sub> was consistently detected in 12 of 21 aquifer-monitoring wells. Concentrations in these wells varied from 0.2–6.8 µg/L, with two wells (M7S and RWMC Production) exceeding the MCL. This is down from four wells in FY 2003. The nine wells where CCl<sub>4</sub> was not detected are M1S, M4D, M11S, M12S, M13S, USGS-89, USGS-117, USGS-119, and USGS-127. Four of these wells (M11S, M12S, M13S, and USGS-127) are more than 2.4 km (1.5 mi) from the SDA.

Figure 4-7 shows the concentration time history of CCl<sub>4</sub> in RWMC-vicinity wells. Although concentrations have increased over the past several years, data from the last few years indicate a flat trend in most wells. Wells A11A31 and USGS-120 show a decreasing trend over the past few years.

#### 4.1.4 Summary of Carbon Tetrachloride

Carbon tetrachloride was detected in FY 2004 in waste zone soil gas, vadose zone soil gas, and in the aquifer in and around the RWMC. None of the perched water samples obtained in FY 2004 were analyzed for organics due to limited sample volumes. The highest soil-gas concentration was 79,600 ppmv, measured in the waste zone soil gas. The maximum soil-gas concentration outside the waste zone was 4,030 ppmv measured in Well 8902, Port 6, at 24 m (78 ft) bls. Soil-gas concentrations at many locations were higher than usual in FY 2004 due to the shutdown of two VVET units for a majority of the year. Nevertheless, CCl<sub>4</sub> concentrations in vadose zone soil gas are appreciably lower since the OCVZ Project began operation of a VVET system.

In FY 2004, low levels of CCl<sub>4</sub> were consistently detected in aquifer-monitoring wells in and around the RWMC. The maximum concentration was 6.8 µg/L measured in the RWMC Production Well. Measured concentrations exceeded the MCL of 5 µg/L in only two wells (M7S and the RWMC Production Well), down from four wells in FY 2003. Although concentrations in some wells have increased over the past several years, the data indicate a relatively flat and perhaps slightly declining trend in many wells during the past few years. No wells exhibited an obvious increasing trend over the past few years, but Wells USGS-120 and A11A31 show a decreasing trend.



Tetrachloroethene was detected in all of the probes that yielded a vapor sample in FY 2004. Table 4-1 contains the PCE results as well as results for the other gases for which analyses were performed. Tetrachloroethene concentrations in the Depleted Uranium Focus Area (west end of Pit 10) were very similar to those measured in FY 2003. Concentrations at locations DU-08 and DU-10 were approximately 1,000–2,000 ppmv. In the Series 743 Focus Area, however, FY 2004 concentrations were much greater than FY 2003 levels. Tetrachloroethene concentrations at locations 743-03, 743-08, and 743-18 were approximately 1,000–3,000 ppmv in FY 2004, while in FY 2003, the maximum concentration was 66 ppmv. The maximum PCE concentration measured was 3,680 ppmv at Probe 743-08-VP1 at a depth of 6.4 m (21 ft) bls, in February 2004. This is greater than the estimated equilibrium vapor concentration of CCl<sub>4</sub> in Series 743 sludge (750 ppmv at 10°C). However, the estimated equilibrium vapor concentration for PCE is small, because PCE is estimated to be a small fraction of the VOC components in Series 743 sludge. Nevertheless, results indicate that Series 743 sludge continues to be a source of PCE and other VOCs.

Tetrachloroethene concentrations at all three vapor probe locations in the 743 Focus Area show a similar trend over the quarterly sampling rounds in FY 2004. The first quarter sample results were relatively low, consistent with the previous year. In the second quarter, however, the results increased dramatically. Third and fourth quarter results were much less than the second quarter, but greater than the first quarter results. A likely possibility for this is that, after the first quarter samples were taken, three soil moisture probes (743-03-M2, 743-18-M2, and 743-18-M3) were installed in the 743 Focus Area near the vapor probes. Relatively “fresh” sludge could have been disturbed by installation of the probe releasing VOCs into the subsurface.

Waste zone soil-moisture samples were not analyzed for VOCs in FY 2004 because of limited sample volumes and analytical priorities.

#### **4.2.2 Vadose Zone**

**4.2.2.1 Perched Water and Lysimeter.** Vadose zone soil-moisture samples collected by WAG 7 were not analyzed for VOCs in FY 2004 because of limited sample volumes and analytical priorities. Samples collected by WAG 7 have not been analyzed for VOCs since September 2000.

U.S. Geological Survey personnel attempted to collect a perched water sample from Well USGS-92 in April 2004, but there was insufficient water for a sample. A perched water sample was obtained from Well USGS-92 in May 2004, but it was not analyzed for organics. Tetrachloroethene has been detected consistently in Well USGS-92 since 1987. The maximum concentration measured was 180 µg/L on February 29, 1996, and the minimum was 23 µg/L on March 30, 1999. Since the OCVZ Project began operating the VVET system, PCE concentrations in perched water from Well USGS-92 have declined.

**4.2.2.2 Soil Gas.** Tetrachloroethene has been detected consistently in soil gas at the RWMC for several years, but at much lower concentrations than CCl<sub>4</sub>. Before FY 2002, the historic maximum PCE concentration was 135 ppmv in Well 8902, Port 4, at a depth of 39 m (130 ft) on January 4, 1996. This was immediately prior to the VVET system beginning full-scale operations. Since April 1998, the PCE concentrations in Well 8902, Port 4, have been less than 10 ppmv.

Since June 2002, there have been several anomalously high PCE measurements, which occurred almost exclusively at Wells 77-1 and 78-4. Validity of these results is highly questionable for two reasons. First, the wells are more than 305 m (1,000 ft) from an organic sludge disposal area. Second, just before the dramatic increase in concentration at these wells, sulfur hexafluoride (SF<sub>6</sub>) gas was used for a gas tracer test in these two wells. It is very likely that the SF<sub>6</sub> interferes with the PCE filter on the Brüel



and Kjær gas analyzer. Since the tracer test, the number of anomalous readings has decreased, but they still persist. The maximum PCE concentration in soil gas in FY 2004 was 107 ppmv in Well 77-1, Port 4, at a depth of 32 m (104 ft) on October 7, 2003. The last sample analyzed in FY 2004 from this same port was 47 ppmv measured on September 1, 2004. Because PCE concentrations at this location before the SF<sub>6</sub> tracer test were less than 20, it appears that the SF<sub>6</sub> interference still persists, but the PCE concentrations are decreasing.

If the questionable high concentrations at Wells 77-1 and 78-4 are not considered, the maximum PCE concentration measured in FY 2004 was 67 ppmv at Well 2E, Port 1, at a depth of 27 m (88 ft) on March 1, 2004. Only one other measurement was above 50 ppmv during FY 2004, and that was at Well IE6, Port 2. The majority of the PCE results were quite low. For example, of all the PCE vadose zone soil-gas results in FY 2004, more than 90 percent were less than 5 ppmv. A histogram displays this in Figure 4-8.

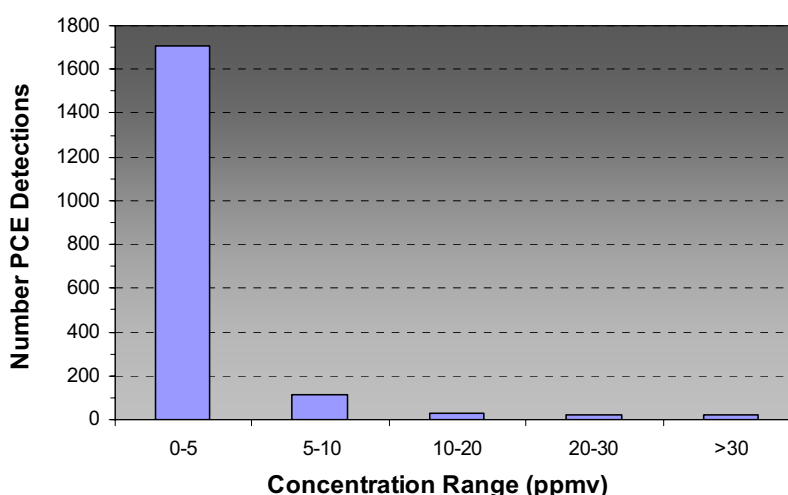


Figure 4-8. Histogram showing the detection frequencies of tetrachloroethene in vadose zone soil gas samples collected during FY 2004 in the vicinity of the Radioactive Waste Management Complex.

#### 4.2.3 Snake River Plain Aquifer

Sixty-eight aquifer samples were collected in FY 2004 from 21 monitoring wells in the vicinity of the RWMC and were analyzed for VOCs. Forty-seven of the samples were collected by WAG 7 personnel from 15 monitoring wells (i.e., Wells AllA31, M1S, M3S, M4D, M6S, M7S, M11S, M12S, M13S, M14S, M15S, M16S, M17S, OW2, and USGS-127). None of the 62 samples had PCE detections above the quantitation limit of 1 µg/L. Two of the samples, both collected from Well M7S, had estimated concentrations (J flag) of 0.34 and 0.46 µg/L.

Nineteen of the 68 aquifer samples were collected by USGS personnel from six aquifer wells in the vicinity of the RWMC. Samples were collected monthly from the RWMC Production Well; in October 2003 from Wells USGS-87, USGS-89, and USGS-120; and then in April 2004 from Wells USGS-87, USGS-89, USGS-117 and USGS-119. Fifteen of the 19 samples had PCE detections above the USGS minimum reporting level of 0.1 µg/L. The maximum concentration measured was 0.3 µg/L in the RWMC Production Well. This value was measured four times in the RWMC Production Well in FY 2004 compared to only once in FY 2003, and VOC data from the USGS could only be obtained through August 2004. The September sample from the RWMC Production Well was not included in this discussion.

Positive detections of PCE in SDA-vicinity aquifer wells are infrequent. The historical maximum PCE concentration measured was 0.4 µg/L in Well M7S on five different occasions from 1993 to 1996. This is far below the MCL of 5 µg/L.

#### 4.2.4 Summary of Tetrachloroethene

Tetrachloroethene was detected in FY 2004 in waste zone soil gas, vadose zone soil gas, and in the aquifer in the vicinity of the RWMC. None of the perched water samples obtained in FY 2004 were analyzed for organics due to limited sample volumes. The maximum soil-gas concentration was 2,274 ppmv measured in the waste zone. Excluding a few questionable high measurements, likely due to interference from a tracer gas (SF<sub>6</sub>) used in 2002, the maximum PCE concentration in vadose zone soil gas was 67 ppmv. Over 90 percent of the PCE soil gas results were less than 5 ppmv.

Positive detections of PCE in SDA-vicinity aquifer wells are infrequent. The maximum aquifer concentration measured in FY 2004 was 0.3 µg/L from the RWMC Production Well. A concentration of 0.46 µg/L was estimated (J-flag) for Well M7S, but this is below the quantitation limit of 1 µg/L. Aquifer results are consistent with the FY 2003 results, because there does not appear to be an increasing or decreasing trend.

### 4.3 Methylene Chloride

Approximately 1.4E+04 kg of methylene chloride were buried in the SDA (Holdren et al. 2002). Information about methylene chloride disposal is scant compared to that for other, more prevalent VOCs like CCl<sub>4</sub>. It should be noted that methylene chloride is a degradation byproduct of CCl<sub>4</sub>; thus, considering the large mass of CCl<sub>4</sub> buried in the SDA, detections of methylene chloride in samples might not necessarily be related to the original inventory buried in the SDA.

#### 4.3.1 Waste Zone

The INNOVA instrument used to analyze soil-vapor probe samples from the waste zone is not set up to detect methylene chloride. Therefore, only duplicate gas samples from the soil-vapor probes that are sent to a laboratory are analyzed for methylene chloride. In FY 2004, methylene chloride was identified above the method detection limit in four of 11 samples from six different probes, yet one of those detections was below the practical quantitation limit (J-flag). The maximum concentration was 980 ppmv measured on September 27, 2004, at Probe 743-08-VP1 at a depth of 6.4 m (21 ft). The maximum concentration in FY 2003 was 710 ppmv at the same probe location. The methylene chloride results from vapor probe sampling are shown in Table 4-3.

Table 4-3. Fiscal Year 2004 methylene chloride vapor concentration results from soil-vapor probes in the Subsurface Disposal Area.

Probe	Port Depth (ft)	Date Sampled	Sample No.	Methylene Chloride (ppmv) <sup>a</sup>
743-08-VP1	21	5/27/04	IPV34201HU	U
		9/27/04	IPV358013A	980
		9/28/04	IPV358013ADL	U
743-08-VP2	14	2/17/04	IPV32701VT	U
		5/27/04	IPV34301HU	U
743-18-VP4	15	11/11/03	IPV31501VT	9.8 <sup>b J</sup>

Table 4-3. (continued).

Probe	Port Depth (ft)	Date Sampled	Sample No.	Methylene Chloride (ppmv) <sup>a</sup>
DU-08-VP2	16	2/17/04	IPV31601VT	450
		5/26/04	IPV33201HU	U
DU-10-VP2	11	5/26/04	IPV33401HU	U
		9/27/04	IPV350013A	U
DU-14-VP2	12	11/10/03	IPV30501VT	210

a. U = undetected

b. Concentrations with a “J” subscript were positively identified in the sample and assigned a “J” data qualifier flag. The qualifier flag was assigned, because the recovery of one of the surrogates was slightly above the upper control limit. The reported concentrations might not be an accurate representation of the amount actually present in the sample and should only be used as estimated quantities. As a result, J-flag data were not considered for the maximum concentration level.

Waste zone soil-moisture samples were not analyzed for VOCs in FY 2004 due to limited sample volumes and analytical priorities.

#### 4.3.2 Vadose Zone

**4.3.2.1 Perched Water and Lysimeter.** Vadose zone soil-moisture samples collected by WAG 7 were not analyzed for VOCs in FY 2004 because of limited sample volumes and analytical priorities. Samples collected by WAG 7 have not been analyzed for VOCs since September 2000.

Personnel from the USGS attempted to collect a perched water sample from Well USGS-92 in April 2004, but there was insufficient water for a sample. A perched water sample was obtained in May 2004 from Well USGS-92, but it was not analyzed for organics. From 1997 until 2003, methylene chloride had been consistently detected in Well USGS-92. Before that, it was analyzed for but not detected above the minimum reporting level of 0.2 µg/L. The maximum methylene chloride concentration in perched water from Well USGS-92 was 22.4 µg/L on April 17, 2001. The last perched water sample analyzed from Well USGS-92 was collected in April 2003 and contained less than 0.2 µg/L methylene chloride.

**4.3.2.2 Soil Gas.** None of the soil gas samples collected from the vadose zone vapor sampling ports since FY 2001 have been analyzed for methylene chloride. However, of the hundreds of samples collected before FY 2002 and analyzed for methylene chloride, only five returned positive detections, and the concentrations were relatively low compared to other VOCs (e.g., CCl<sub>4</sub>, chloroform, 1,1,1-trichloroethane, trichloroethene [TCE], and PCE).

#### 4.3.3 Snake River Plain Aquifer

Sixty-eight aquifer samples were collected in FY 2004 from 21 monitoring wells in the vicinity of the RWMC and analyzed for VOCs. Forty-seven of the samples were collected by WAG 7 personnel from 15 monitoring wells (i.e., Wells AllA31, M1S, M3S, M4D, M6S, M7S, M11S, M12S, M13S, M14S, M15S, M16S, M17S, OW2, and USGS-127). Only one of the 62 samples had a detection of methylene chloride above the quantitation limit of 1 µg/L.

Personnel from the USGS collected 19 of the 68 aquifer samples from six aquifer wells in the vicinity of the RWMC. Samples were collected by the USGS monthly from the RWMC Production Well; in October 2003 from Wells USGS-87, USGS-89, and USGS-120; and then in April 2004 from Wells USGS-87, USGS-89, USGS-117, and USGS-119. None of the 19 samples had detection greater

than or equal to the USGS minimum reporting level of 0.2 µg/L. It should be mentioned that VOC data from the USGS could be obtained only through August 2004. The September sample from the RWMC Production Well was not included in this discussion.

Positive detections of methylene chloride in SDA-vicinity aquifer wells are infrequent. The historical maximum methylene chloride concentration measurement was 8 µg/L in Well M10S, collected on July 22, 1996, which is greater than the MCL of 5 µg/L. However, five of the total seven detections historically were during the same sampling round (July 1996), which raises the question as to whether the samples were cross-contaminated before or during analysis. Methylene chloride was reported at 2.8 µg/L in Well M1S in November 2002, but it was also detected in the associated blank. Except for this, methylene chloride has not been detected in any aquifer wells since October 1997.

#### 4.3.4 Summary of Methylene Chloride

Methylene chloride was detected in four of 11 soil-vapor samples taken from vapor probes in the waste zone. The maximum concentration was 980 ppmv. No lysimeter, perched water, or vadose zone soil-gas samples were analyzed for methylene chloride in FY 2004. In all of the 68 aquifer samples collected, methylene chloride was not detected above the quantitation limit of 1 µg/L (WAG 7 wells) or the minimum reporting level of 0.2 µg/L (USGS wells).

### 4.4 Other Organic Contaminants

Series 743 waste is known to contain other organic compounds (e.g., 1,1,1-trichloroethane and PCE). These organic compounds have been detected in virtually all media in an around the SDA. The estimated mass of 1,1,1-trichloroethane and PCE in Series 743 sludge is 8.19E+04 kg and 8.92E+04 kg, respectively (Varvel 2005). Chloroform detections are also prevalent at the SDA, but records indicate very little chloroform was buried. Most of the chloroform is believed to be a degradation product of CCl<sub>4</sub>. Disposal amounts of other organic compounds are very small compared to the amounts in Series 743 sludge.

#### 4.4.1 Waste Zone

Besides CCl<sub>4</sub> and PCE, gas samples collected from vapor probes placed in the waste in Pits 4 and 10 were analyzed for chloroform, 1,1,1-trichloroethane (1,1,1-TCA), and TCE using the INNOVA Model 1314 photoacoustic multigas analyzer. Some of the field duplicate samples also were analyzed using standard laboratory GC/MS as an accuracy check on the INNOVA results. The duplicate samples were analyzed for several other VOCs.

Chloroform, 1,1,1-TCA, and TCE were detected in all of the waste-zone vapor probes that yielded a vapor sample. Other VOCs detected in the samples analyzed by GC/MS include chloromethane, 1,1-dichloroethane, and 1,1,2-trichloro-1,2,2-trifluoroethane (Freon-113). Table 4-4 shows the maximum results for each of the other organics identified in the vapor probes samples.

Table 4-4. Maximum concentrations of other organics detected in soil gas from waste zone vapor probes.

Organic Compound	Sample Date	Well Port	Depth (ft)	Concentration (ppmv)
Trichloroethene	9/28/04	743-08-VP1	21	14,000
1,1,1-Trichloroethane	11/10/03	DU-08-VP2	16	3,810
Chloroform	9/28/04	743-08-VP1	21	18,000

Table 4-4. (continued).

Organic Compound	Sample Date	Well Port	Depth (ft)	Concentration (ppmv)
Chloromethane	9/27/04	743-08-VP1	21	1,400
Freon-113 <sup>a</sup>	9/27/04	743-08-VP1	21	200
1,1-Dichloroethane	9/27/04	DU-10-VP2	11	45

a. Freon-113 = 1,1,2-trichloro-1,2,2-trifluoroethane

Waste zone soil-moisture samples were not analyzed for VOCs in FY 2004 due to limited sample volumes and analytical priorities.

#### 4.4.2 Vadose Zone

**4.4.2.1 Perched Water and Lysimeter.** Vadose zone soil-moisture samples collected by WAG 7 were not analyzed for VOCs in FY 2004 due to limited sample volumes and analytical priorities. Samples collected by WAG 7 have not been analyzed for VOCs since September 2000.

Personnel from the USGS attempted to collect a perched water sample from Well USGS-92 in April 2004, but there was insufficient water for a sample. A perched water sample was obtained in May 2004 from Well USGS-92, but it was not analyzed for organics. In general, TCE, 1,1,1-TCA, and chloroform are historically the only other organics consistently detected in perched water.

**4.4.2.2 Soil Gas.** Chloroform, 1,1,1-TCA, and TCE are the only other VOCs for which analysis is performed on vadose zone soil-gas samples routinely collected at the SDA. All three compounds are ubiquitous in the vicinity of the RWMC, but at much lower concentrations than CCl<sub>4</sub>. Nevertheless, the trends are very similar to the CCl<sub>4</sub> concentrations. Figure 4-9 contains histograms showing the detection frequencies for chloroform, 1,1,1-TCA, and TCE in vadose zone soil-gas samples collected during FY 2004. The majority of the results are less than 5 ppmv for all three compounds.

The maximum concentrations of chloroform, 1,1,1-TCA and TCE detected in FY 2004 both inside and outside of the SDA are shown in Table 4-5.

Table 4-5. Maximum concentrations of trichloroethene, 1,1,1-trichloroethane, and chloroform detected in vadose zone soil gas inside and outside of the Subsurface Disposal Area in Fiscal Year 2003.

Organic Compound	Inside or Outside the Subsurface Disposal Area	Sample Date	Well Port	Depth (ft)	Concentration (ppmv)
Chloroform	Inside	3/1/04	8801-4	78	1,030
1,1,1-Trichloroethane	Inside	3/1/04	2E-1	88	370
Trichloroethene	Inside	12/1/03	8902-6	71	523
Chloroform	Outside	8/4/04	2V-4	43	35
1,1,1-Trichloroethane	Outside	5/3/04	77-1-4	111	10
Trichloroethene	Outside	12/1/03	2V-1	198	23

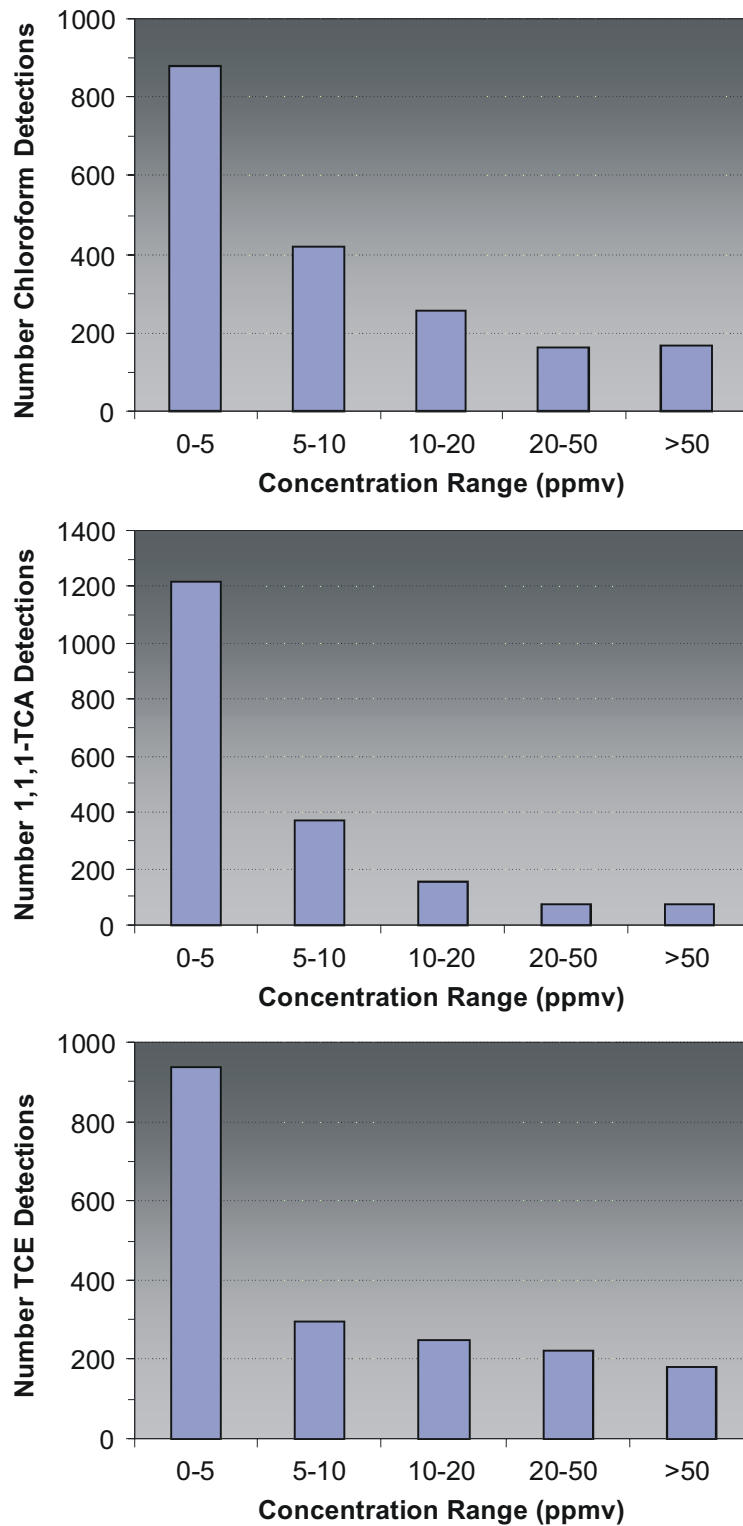


Figure 4-9. Histograms showing the detection frequencies for chloroform, 1,1,1-trichloroethane, and trichloroethene in vadose zone soil gas samples collected during Fiscal Year 2004 in the vicinity of the Radioactive Waste Management Complex.

#### 4.4.3 Snake River Plain Aquifer

In addition to CCl<sub>4</sub>, PCE, and methylene chloride, RWMC aquifer samples in FY 2004 were analyzed for other VOCs and most were nondetections. Chloroform, TCE, 1,1,1-TCA, and toluene were the only compounds detected at concentrations above the quantitation limit (WAG 7 wells) or minimum reporting levels (USGS wells). All compounds were below the respective MCLs. Table 4-6 contains the results for all detections of other organics from aquifer samples.

Table 4-6. Concentration of other volatile organic compounds detected in the aquifer in the vicinity of the Radioactive Waste Management Complex in Fiscal Year 2004.

Organic Compound	Sample Date	Well	Sample Concentration (µg/L)	Quantitation Limit or Minimum Reporting Level (µg/L)	MCL (µg/L)
Waste Area Group 7 Monitoring Results					
Chloroform	12/1/03	M7S	0.61 <sub>J</sub> <sup>a</sup>	1.0	100
	12/1/03	M16S	0.51 <sub>J</sub> <sup>a</sup>	1.0	100
	12/2/03	A11A31	1	1.0	100
	12/3/03	M15S	0.39 <sub>J</sub> <sup>a</sup>	1.0	100
	1/20/04	M7S	0.5 <sub>J</sub> <sup>a</sup>	1.0	100
	1/20/04	A11A31	0.83 <sub>J</sub> <sup>a</sup>	1.0	100
	1/21/04	M16S	0.42 <sub>J</sub> <sup>a</sup>	1.0	100
	4/26/04	A11A31	0.9 <sub>J</sub> <sup>a</sup>	1.0	100
	5/3/04	M6S	0.41 <sub>J</sub> <sup>a</sup>	1.0	100
	5/4/04	M15S	0.38 <sub>J</sub> <sup>a</sup>	1.0	100
	5/4/04	M16S	0.49 <sub>J</sub> <sup>a</sup>	1.0	100
	5/4/04	M16S	0.53 <sub>J</sub> <sup>a</sup>	1.0	100
	5/5/04	M7S	0.73 <sub>J</sub> <sup>a</sup>	1.0	100
Trichloroethene	12/1/03	M6S	0.76 <sub>J</sub> <sup>a</sup>	1.0	5
	12/1/03	M7S	1.80	1.0	5
	12/1/03	M16S	1.80	1.0	5
	12/2/03	M3S	0.54 <sub>J</sub> <sup>a</sup>	1.0	5
	12/2/03	A11A31	2.10	1.0	5
	12/3/03	M17S	0.42 <sub>J</sub> <sup>a</sup>	1.0	5
	12/3/03	M15S	0.82 <sub>J</sub> <sup>a</sup>	1.0	5
	1/20/04	M6S	0.47 <sub>J</sub> <sup>a</sup>	1.0	5
	1/20/04	M7S	1.8	1.0	5
	1/20/04	A11A31	2	1.0	5
	1/21/04	M16S	1.7	1.0	5
	1/27/04	M3S	0.53 <sub>J</sub> <sup>a</sup>	1.0	5
	1/27/04	M15S	0.69 <sub>J</sub> <sup>a</sup>	1.0	5
	4/26/04	A11A31	1.7	1.0	5
	4/27/04	M3S	0.64 <sub>J</sub> <sup>a</sup>	1.0	5
	5/3/04	M6S	0.95 <sub>J</sub> <sup>a</sup>	1.0	5
	5/4/04	M15S	0.9 <sub>J</sub> <sup>a</sup>	1.0	5
	5/4/04	M16S	1.9	1.0	5

Table 4-6. (continued).

Organic Compound	Sample Date	Well	Sample Concentration (µg/L)	Quantitation Limit or Minimum Reporting Level (µg/L)	MCL (µg/L)
Trichloroethene	5/4/04	M16S	1.8	1.0	5
	5/5/04	M7S	2.5	1.0	5
1,1,1-TCA	12/1/03	M7S	0.45 <sub>J</sub> <sup>a</sup>	1.0	200
	12/1/03	M16S	0.46 <sub>J</sub> <sup>a</sup>	1.0	200
	12/2/03	A11A31	0.37 <sub>J</sub> <sup>a</sup>	1.0	200
	1/20/04	M7S	0.49 <sub>J</sub> <sup>a</sup>	1.0	200
	5/4/04	M16S	0.39 <sub>J</sub> <sup>a</sup>	1.0	200
	5/4/04	M16S	0.43 <sub>J</sub> <sup>a</sup>	1.0	200
	5/5/04	M7S	0.59 <sub>J</sub> <sup>a</sup>	1.0	200
Toluene	12/1/03	M7S	3.1	1.0	1,000
	12/2/03	A11A31	6.3	1.0	1,000
	12/3/03	M15S	24 <sup>b</sup>	1.0	1,000
	1/20/04	M7S	3.1	1.0	1,000
	1/27/04	M15S	13	1.0	1,000
	4/26/04	A11A31	0.63 <sub>J</sub> <sup>a</sup>	1.0	1,000
	5/4/04	M15S	4	1.0	1,000
	5/5/04	M7S	3	1.0	1,000
United States Geological Survey Monitoring Results					
Chloroform	10/9/03	RWMC Production	1	0.1	100
	11/13/03	RWMC Production	1.2	0.1	100
	12/18/03	RWMC Production	1.3	0.1	100
	1/15/04	RWMC Production	1	0.1	100
	1/15/04	RWMC Production	1	0.1	100
	2/12/04	RWMC Production	1.2	0.1	100
	3/11/04	RWMC Production	1.1	0.1	100
	4/8/04	RWMC Production	1.3	0.1	100
	5/12/04	RWMC Production	1.4 <sup>b</sup>	0.1	100
	6/10/04	RWMC Production	1.1	0.1	100
	7/8/04	RWMC Production	1.2	0.1	100
	8/12/04	RWMC Production	1.3	0.1	100
	10/9/03	USGS-087	0.1	0.1	100
	4/8/04	USGS-087	0.2	0.1	100
	10/9/03	USGS-120	0.5	0.1	100
Trichloroethene	10/9/03	RWMC Production	2.3	0.1	5
	11/13/03	RWMC Production	2.6	0.1	5
	12/18/03	RWMC Production	3 <sup>b</sup>	0.1	5
	1/15/04	RWMC Production	2.5	0.1	5
	1/15/04	RWMC Production	2.5	0.1	5
	2/12/04	RWMC Production	2.8	0.1	5
	3/11/04	RWMC Production	2.3	0.1	5
	4/8/04	RWMC Production	2.7	0.1	5



Table 4-6. (continued).

Organic Compound	Sample Date	Well	Sample Concentration (µg/L)	Quantitation Limit or Minimum Reporting Level (µg/L)	MCL (µg/L)
Trichloroethene	5/12/04	RWMC Production	<b>3<sup>b</sup></b>	0.1	5
	6/10/04	RWMC Production	2.4	0.1	5
	7/8/04	RWMC Production	2.5	0.1	5
	8/12/04	RWMC Production	<b>3<sup>b</sup></b>	0.1	5
	10/9/03	USGS-087	0.7	0.1	5
	4/8/04	USGS-087	0.7	0.1	5
	10/9/03	USGS-120	0.9	0.1	5
1,1,1-TCA	10/9/03	RWMC Production	<b>0.5<sup>b</sup></b>	0.1	200
	11/13/03	RWMC Production	<b>0.5<sup>b</sup></b>	0.1	200
	12/18/03	RWMC Production	<b>0.5<sup>b</sup></b>	0.1	200
	1/15/04	RWMC Production	<b>0.5<sup>b</sup></b>	0.1	200
	1/15/04	RWMC Production	<b>0.5<sup>b</sup></b>	0.1	200
	2/12/04	RWMC Production	<b>0.5<sup>b</sup></b>	0.1	200
	3/11/04	RWMC Production	<b>0.5<sup>b</sup></b>	0.1	200
	4/8/04	RWMC Production	<b>0.5<sup>b</sup></b>	0.1	200
	5/12/04	RWMC Production	<b>0.5<sup>b</sup></b>	0.1	200
	6/10/04	RWMC Production	<b>0.5<sup>b</sup></b>	0.1	200
	7/8/04	RWMC Production	<b>0.5<sup>b</sup></b>	0.1	200
	8/12/04	RWMC Production	<b>0.5<sup>b</sup></b>	0.1	200
	10/9/03	USGS-087	0.2	0.1	200
	4/8/04	USGS-087	0.2	0.1	200
	10/9/03	USGS-120	0.3	0.1	200

a. Concentrations with a "J" subscript were positively identified in the sample and assigned a "J" data qualifier flag. The qualifier flag was assigned, because the recovery of one of the surrogates was slightly above the upper control limit. The reported concentrations might not be an accurate representation of the amount actually present in the sample and should only be used as estimated quantities. As a result, J-flag data were not considered for the maximum concentration level.

b. **Bold font** indicates maximum concentration detected.

1,1,1-TCA = 1,1,1-trichloroethane

MCL = maximum contaminant level

RWMC = Radioactive Waste Management Complex

USGS = U.S. Geological Survey

Chloroform was detected in Well A11A31 above a quantitation limit of 1 µg/L, and in Wells USGS-87, USGS-120, and the RWMC Production Well above a minimum reporting level of 0.1 µg/L. The maximum concentration of chloroform in FY 2004 was 1.4 µg/L, down from 1.7 in FY 2003. Trichloroethene was detected in Wells A11A31, M7S, and M16S above a quantitation limit of 1 µg/L, and in Wells USGS-87, USGS-120, and the RWMC Production Well above a minimum reporting level of 0.1 µg/L. The maximum concentration in FY 2004 was 3, the same as in FY 2003.

1,1,1-Trichloroethane was not detected in any WAG 7 monitoring wells above a quantitation limit of 1 µg/L. However, 1,1,1-trichloroethane was detected in the RWMC Production Well and Wells USGS-87 and USGS-120 above a minimum reporting level of 0.1 µg/L. The maximum 1,1,1-trichloroethane concentration in FY 2004 was 0.5 µg/L, down slightly from 0.6 in FY 2003. Toluene was detected consistently in Wells M7S, M15S, and A11A31, and the maximum concentration in FY 2004 was 24 µg/L, down from 47 in FY 2003. Samples were analyzed for up to 54 other organic compounds, but

none were detected above the quantitation limits (WAG 7 wells) or minimum reporting levels (USGS wells).

#### **4.4.4 Summary**

Other organics detected during sampling at the RWMC include chloroform, 1,1,1-TCA, TCE, Freon-113, 1,1-dichloroethane, chloromethane, and toluene. All organics, except for toluene, were detected in waste zone soil gas.

During aquifer monitoring in FY 2004, only four other organic compounds (i.e., TCE, 1,1,1-TCA, chloroform, and toluene) were detected in 68 samples. All sample results were below MCLs. Toluene had the highest concentration (i.e., 24 µg/L) measured in Well M15S. The maximum TCE concentration (i.e., 3 µg/L), the maximum chloroform concentration (i.e., 1.4 µg/L), and the maximum 1,1,1-TCA concentration (i.e., 0.5 µg/L) were all from the RWMC Production Well.

Detections of TCE and 1,1,1-TCA are not surprising, because those were components of Series 743 sludge. Chloroform detections also are not surprising, because it is likely being produced by degradation of the CCl<sub>4</sub>. Detections of the other organics like Freon-113 and 1,1-dichloroethane (soil gas), and toluene (groundwater) are low-level detections and will continue to be monitored.

## 5. INORGANIC CONTAMINANTS

Numerous anion and cation analysis results were significantly above soil-moisture (lysimeter) background concentrations in FY 2004, and a few results exceeded MCLs. Most anions and cations are not COCs and have little to no associated risk; however, some are very mobile (e.g., chloride and sodium) and provide good early warning indicators of contamination movement in the vadose zone at the SDA. The analysis results of many cations varied drastically in FY 2004. Many of the extreme values seem implausible, because of their inconsistency with past sampling results. In all probability, many of these extreme values are not representative of conditions in the vadose zone. Many of the maximum range values listed in the tables below were not replicated in subsequent sampling events. In addition, some of the high values are possibly analytical anomalies, even though the reported data passed evaluation scrutiny. Interpretation of such inconsistent results is difficult, because many of the anions and cations are indigenous to the environment and are naturally variable. Interpretation of analytical data in the vadose zone is also compounded by the presence of magnesium chloride brine dust suppressant, leachates from waste, possible corrosion of the lysimeter units, and potential analytical anomalies. Many of the cations data are not providing useful information at this point. Only those cations data providing useful information are discussed below.

Each quarter, approximately 400 inorganic analysis results are generated; therefore, to reduce the size of the tables, analytes that exceeded background concentrations and MCLs during FY 2004 are shown with the concentration range observed during FY 2004, except for nitrates. Because nitrates are one of the COCs for OU 7-13/14, they are discussed separately in Section 5.1, followed by a discussion of other inorganic contaminants in Section 5.2.

### 5.1 Nitrates

#### 5.1.1 Waste Zone

Eighteen waste zone lysimeters were sampled every quarter in FY 2004, and Lysimeters 741-08-L1 and 743-18-L2, located in Pits 10 and 4, respectively, were the only waste zone lysimeters to yield soil moisture samples. The sample volume was very small and allocated to radionuclide analyses. Therefore, nitrate (as nitrogen) analyses were not performed on waste zone soil moisture samples in FY 2004.

#### 5.1.2 Vadose Zone

##### **5.1.2.1 Subsurface Soil Samples Collected While Drilling Lysimeter Well RWMC-2005.**

In April 2004, while drilling lysimeter Well RWMC-2005 in the east end of the SDA (see Figure 2-3), radioactivity above background was detected in the drilling soil returns. Drilling was stopped, and three separate soil samples were collected from these returns. The samples were analyzed for nitrates, which were detected in all three samples (see Table 5-1).

**5.1.2.2 Lysimeter Samples at Depths of 0–35 ft.** Twelve nitrate (as nitrogen) analyses were performed on samples collected from nine lysimeter wells in and around the SDA in FY 2004, with three detections above local soil-moisture background and above the MCL (see Table 5-2). The primary drinking water MCL is not applicable to soil-moisture samples, but it is used as a basis for comparison.

Nitrate concentrations in the shallow region of the vadose zone during FY 2004 show wide variations, ranging from 0.4 mg/L in Well PA01 to 99.8 mg/L in Well PA02. Background levels of nitrate in the vadose zone outside the SDA typically range from 0.1–11.4 mg/L. The highest nitrate concentrations were measured in Well PA02, which is adjacent to Pad A where nitrate-laden waste is buried. Nitrate concentrations at well location PA01 showed a sudden and significant increase in FY 2004

(see Figure 5-1), where concentrations at Well W25 showed a gradual but steady increase over time (see Figure 5-1). Nitrates in the Pad A area appear to have migrated to a depth of about 30 m (100 ft); nitrate concentrations at this 30-m (100-ft) depth also are above background (see results of Lysimeter I4S:DL11 in Table 5-3). Another area where elevated nitrate levels are consistently measured is west of Pit 4 in two adjacent wells (i.e., Wells 98-4 and W-25). A few hundred feet west of this location, at a 28-m (92-ft) depth, is Well I2S, which also contains elevated and trending nitrate concentrations (see results of Lysimeter I2S:DL11 in Table 5-3 and Figure 5-2).

Table 5-1. Nitrate detected in soil samples collected from lysimeter installation core hole drilled in the east end of the Subsurface Disposal Area.

Analyte	Sample Date	Sample Location	Sample Result (mg/kg)	Method Detection Limit (mg/kg)	INL Soil Background UTL <sup>a</sup> (mg/kg)	Soil Hazard Index = 1 <sup>b</sup> (mg/kg)
Nitrate-N	04/26/04	RWMC-2005	6.01	0.56	NE	NA
			8.88	0.56	NE	NA
			5.33	0.56	NE	NA

a. INL surficial soil background 95% upper tolerance concentration limits for grab samples are not directly applicable to subsurface soils, but are provided here only as a basis for comparison. The surficial soil background tolerance limits were established in 1996 (Rood, Harris, and White 1996).

b. Concentration at which noncarcinogenic health effects can occur.

INL = Idaho National Laboratory

NA = not applicable

NE = not established

UTL = upper 95% tolerance limit with 95% confidence

Table 5-2. Nitrate (as nitrogen) concentration above local soil-moisture background in the 0–35-ft depth interval of the Subsurface Disposal Area vadose zone soil moisture (lysimeter).

Analyte	Sample Date	Well: Lysimeter	Well: Lysimeter Depth (ft)	Sample Result (mg/L)	Local Soil-Moisture Background <sup>a</sup> (mg/L)	MCL <sup>b</sup> (mg/L)
Nitrate-N	10/28/03	PA02:L16	8.7	<b>99.8<sup>c</sup></b>	11.4	10
	10/28/03	W25:L28	15.5	<b>33.9<sup>c</sup></b>	11.4	10
	01/26/04	PA02:L16	8.7	<b>88.9<sub>J</sub><sup>c</sup></b>	11.4	10

a. Local soil-moisture background values are the upper concentration ranges obtained from up to 50 soil-moisture samples collected between April 1987 and August 2004 from lysimeter wells located outside of the SDA (i.e., Wells C01, C02, D15, and the O-series wells).

b. The MCLs are from the “National Primary Drinking Water Standards” (40 CFR 141) established by the EPA. The MCLs for vadose zone water samples are applicable to perched water, but not to soil-moisture (lysimeter) samples. The MCLs for lysimeter sample results are provided here only as a basis for comparison.

c. **Red bold font** indicates sample concentrations that exceed the MCL (see Footnote b). Concentration values with a “J” subscript denote that “J” data validation qualifier flags were assigned. The “J” flag was assigned to the January result because the laboratory was unable to perform an analytical quality check to assess matrix interference. The result is usable, but should only be used as an estimated quantity.

EPA = U.S. Environmental Protection Agency

MCL = maximum contaminant level

SDA = Subsurface Disposal Area

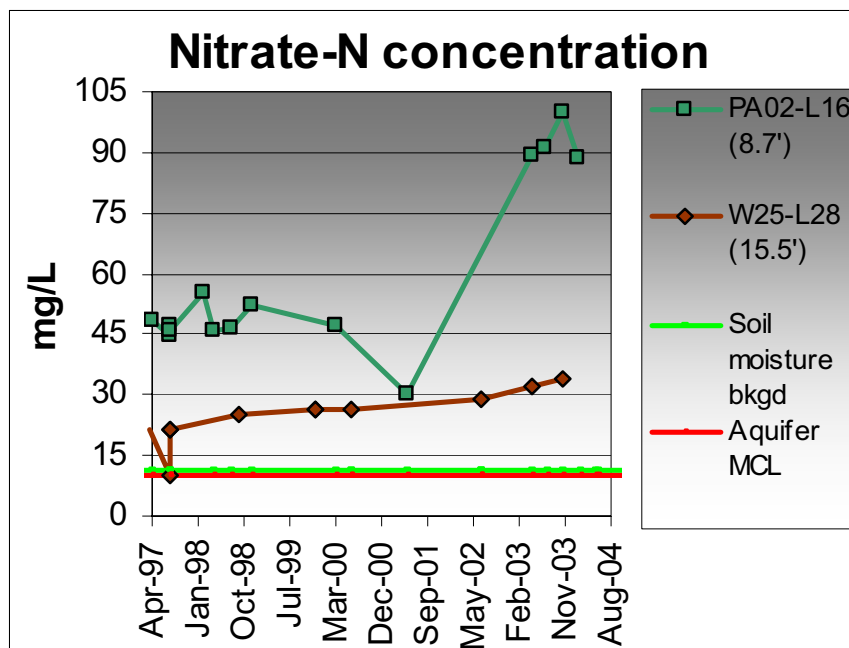


Figure 5-1. Lysimeters in the Subsurface Disposal Area vadose zone exhibiting concentration trends from 1997 through August 2004.

Table 5-3. Nitrate (as nitrogen) concentrations above local soil-moisture background in the 35–140-ft depth interval of the Subsurface Disposal Area vadose zone soil moisture (lysimeter).

Analyte	Sample Date	Well: Lysimeter	Well: Lysimeter Depth (ft)	Sample Result (mg/L)	Local Soil-Moisture Background <sup>a</sup> (mg/L)	MCL <sup>b</sup> (mg/L)
Nitrate-N	10/28/03	D06:DL02	44	<b>14.8<sup>c</sup></b>	11.4	10
	10/27/03	I-2S:DL11	92	<b>106<sup>c</sup></b>	11.4	10
	10/28/03	I-4S:DL15	97	<b>15.7<sup>c</sup></b>	11.4	10
	10/27/04	TW1:DL04	101.7	<b>16.0<sup>c</sup></b>	11.4	10
	02/02/04	I-2S:DL11	92	<b>98.6<sup>c</sup></b>	11.4	10

a. Local soil-moisture background values are the upper concentration ranges obtained from up to 50 soil-moisture samples collected between April 1987 and August 2004 from lysimeter wells located outside of the SDA (i.e., Wells C01, C02, D15, and the O-series wells).

b. The MCLs are from the “National Primary Drinking Water Standards” (40 CFR 141) established by the EPA. The MCLs for vadose zone water samples are applicable to perched water, but not to soil-moisture (lysimeter) samples. The MCLs for lysimeter sample results are provided here only as a basis for comparison.

c. **Red bold font** indicates sample concentrations that exceed the MCL (see Footnote b).

EPA = U.S. Environmental Protection Agency

MCL = maximum contaminant level

SDA = Subsurface Disposal Area

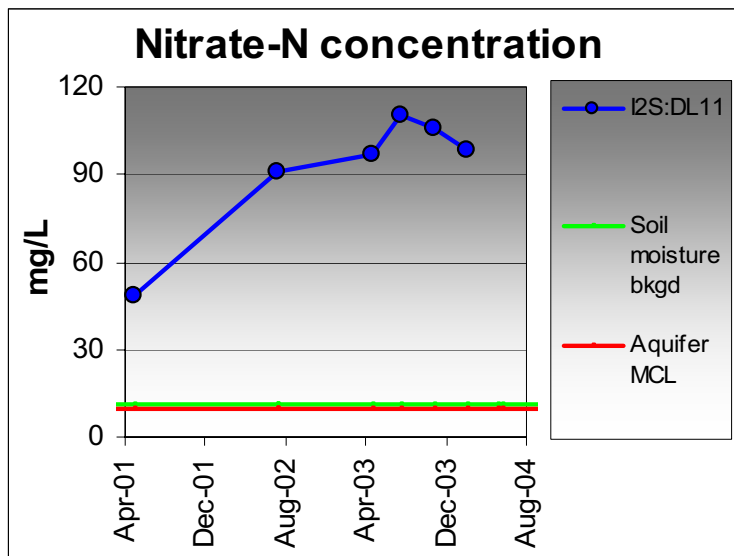


Figure 5-2. Lysimeter in the Subsurface Disposal Area vadose zone exhibiting concentration trend.

**5.1.2.3 Lysimeter Samples at Depths of 35–140 ft.** Twenty-one nitrate (as nitrogen) analyses were performed on samples collected from 13 lysimeter wells in and around the SDA in FY 2004, with five detections above local soil-moisture background (see Table 5-3). All five detections exceeded the drinking water MCL. The primary drinking water MCL is not applicable to soil-moisture samples, but is used as a basis for comparison. Nitrate concentrations in the intermediate vadose zone also show wide variations, ranging from 0.1 mg/L in Well O2S to 110 mg/L in Well I2S. Wells monitored in this depth interval around Pad A (i.e., D06, TW1, and I4S) generally have slightly elevated nitrate concentrations in the range of 12–16 mg/L. Nitrate concentrations in Well I4S show nitrate contamination has migrated to about the 100-ft depth around Pad A. This lysimeter well is located in the same vicinity as the high and trending nitrate concentrations observed in PA02. Well I2S has the highest nitrate concentration observed in the 35–140-ft depth interval, and the concentration is increasing at a fairly significant rate (see Figure 5-2).

**5.1.2.4 Lysimeter Samples at Depths of 140 to 250 ft.** Twenty-eight nitrate (as nitrogen) analyses were performed on samples collected from 16 lysimeters and three perched water wells in and around the SDA in FY 2004, with one lysimeter result above local soil-moisture background and the MCL, and three perched water results above aquifer background (see Table 5-4). The primary drinking water MCL is not applicable to soil-moisture samples, but is used as a basis for comparison. Nitrate concentrations detected in the deep vadose zone soil moisture and perched water are near background levels and indicate much less variation than do nitrate concentrations in the shallow and intermediate vadose zone. Nitrate concentrations in this depth interval range from 0.13 to 15.7 mg/L. It should be noted that the concentration of 15.7 mg/L is associated with Well TW1:DL03. This the first time a soil-moisture sample has been collected from Well TW1:DL03, so it is interesting to observe nitrate concentrations typical of what is usually detected in TW1:DL04 at 32 m (102 ft). One sample result, however, is not sufficient evidence to surmise that nitrates have migrated to 69 m (227 ft), especially because a remote possibility exists that the DL03 and DL04 sample lines could have been switched during this sampling event or that samples were mislabeled.

Table 5-4. Nitrate (as nitrogen) concentrations above local soil-moisture background at depths greater than 140 ft in the Subsurface Disposal Area vadose zone soil moisture (lysimeter).

Analyte	Sample Date	Well: Lysimeter	Well: Lysimeter Depth (ft)	Sample Result (mg/L)	Local Soil-Moisture Background <sup>a</sup> (mg/L)	MCL <sup>b</sup> (mg/L)
Nitrate-N	01/26/04	TW1:DL03	226.9	15.7 <sup>c</sup>	11.4	10

a. Local soil-moisture background values are the upper concentration ranges obtained from up to 50 soil-moisture samples collected between April 1987 and August 2004 from lysimeter wells located outside of the SDA (i.e., Wells C01, C02, D15, and the O-series wells).

b. The MCLs are from the "National Primary Drinking Water Standards" (40 CFR 141) established by the EPA. The MCLs for vadose zone water samples are applicable to perched water, but not to soil-moisture (lysimeter) samples. The MCLs for lysimeter sample results are provided here only as a basis for comparison.

c. **Red bold font** indicates sample concentrations that exceed the MCL (see Footnote b).

EPA = U.S. Environmental Protection Agency

MCL = maximum contaminant level

SDA = Subsurface Disposal Area

### 5.1.3 Aquifer

Fifty nitrate (as nitrogen) analyses were performed on samples collected from 15 RWMC monitoring wells around the RWMC in FY 2004, with no detections above the SRPA background concentration of 1 to 2 mg/L established by Knobel, Orr, and Cecil (1992). At the end of 2004, the frequency at which the RWMC aquifer was monitored changed to biannually; thus, only data from the first three quarters of FY 2004 are available and shown in Figure 3-4. Low levels of nitrates were detected in all RWMC aquifer samples at concentrations characteristic of SRPA background levels, except for Well M6S. Nitrate concentrations in FY 2004 ranged from 0.3 mg/L in Well M13S to 2.0 mg/L in M6S. All results were below the primary drinking water MCL of 10 mg/L. The nitrate concentration measured in January 2004 in Monitoring Well M6S (i.e., 2.02 mg/L) could be construed as exceeding SRPA background (2 mg/L); however, interpretation is dependent on how the result is mathematically rounded. The M6S result at 2.02 mg/L is considered to be representative of aquifer background, but will continue to be monitored for concentration increases. Nitrate levels in M6S have exhibited increasing concentration trends since 1992; however, that trend appears to have stabilized in 2002 at concentrations near the SRPA background (see Figure 5-3).

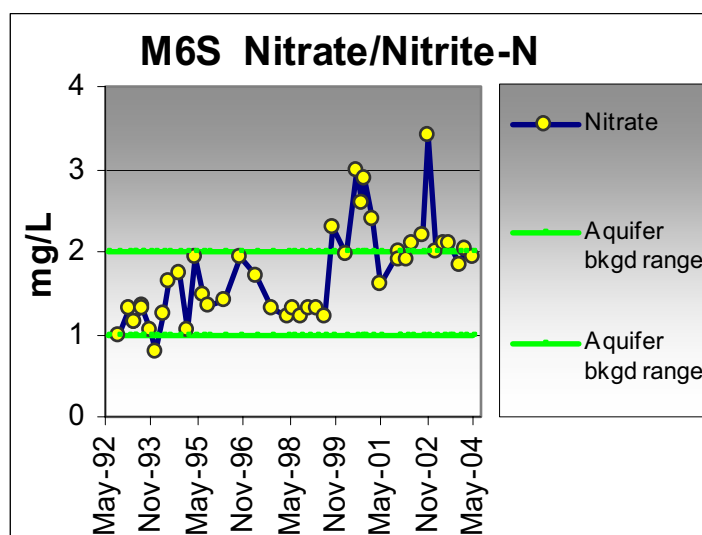


Figure 5-3. Concentration of nitrates (as nitrogen) in Radioactive Waste Management Complex Aquifer Monitoring Well M6S from 1992 to May 2004.

#### 5.1.4 Summary of Nitrates

Low levels of nitrates were detected in all aquifer-monitoring wells in the vicinity of the RWMC in FY 2004 at concentrations characteristic of background levels typically found in the SRPA.

Of the 61 vadose zone soil-moisture and perched water samples collected and analyzed for nitrates in FY 2004, 11 results were above background levels and nine of those 11 exceeded the primary drinking water MCL. Significant concentration trends were associated with Lysimeters PA02:L16 and I2S:DL11, providing evidence that nitrates have migrated to about 30 m (100 ft) in the vadose zone. Nitrate concentrations are highest in the 0–11-m (0–35-ft) and 11–43-m (35–140-ft) regions of the vadose zone, and are most prevalent in lysimeter wells located around the Pit 5 and Pad A area (i.e., Wells D06, I4S, PA02, and TW1), the west end of the SDA (i.e., Well I2S), the west end of Pit 4 (i.e., Wells 98-4 and W25), and the Acid Pit (Well W08). Significant concentration trends are evident at lysimeter well locations PA01 and I2S.

### 5.2 Other Inorganic Contaminants

Numerous anions and cations analysis results were above background in samples collected from RWMC aquifer-monitoring wells and vadose zone soil moisture in FY 2004. Many of these anions and cations have high concentrations that exceed aquifer MCLs. Anion and cation contaminants detected in the vadose zone have relatively high concentrations, and many are attributed to dust-suppression activities at the SDA up to 20 years ago. In 1984, 1985, 1992, and 1993, magnesium chloride brine was applied to roads in the SDA to suppress dust. The chemical constituents of the brine are now widely distributed in the vadose zone at the SDA, and most of the elevated concentrations of cations and anions can be related to the brine application. The primary anion in the brine is chloride, but bromide and sulfate also are present at high concentrations. Elevated calcium, sodium, potassium, and magnesium are related to the brine application. Brine affects the chemistry of soil water by ion exchange, as evidenced by elevated brine constituents and changes in anion ratios. Higher mineral content and altered chemistry of the soil water accelerates the migration of some waste contaminants. Because the chemical constituents of brine are corrosive, they likely have contributed to the premature corrosion and deterioration of waste containers in the SDA.

Brine constituents are consistently detected during routine monitoring of vadose zone soil moisture to depths around 30 m (100 ft), with detections at depths around 67 m (220 ft). Vadose zone sampling and analysis data evaluated in the *Fate of Magnesium Chloride Brine Applied to Suppress Dust from Unpaved Roads at the INEEL Subsurface Disposal Area* (Hull and Bishop 2003) report show evidence that brine has definitely migrated at least 73 m (240 ft) deep at the SDA since 1984, and can move laterally. Vertical migration rates of 6–40 m (20–130 ft) per year were determined for brine constituents (Hull and Bishop 2003), and, at this rate, brine constituents could have reached the aquifer by now. Even though routinely detected, chemical constituents of brine generally are not reported unless concentrations begin to increase or change suddenly, or constituents are detected at deeper depths. Lysimeter and aquifer results for other inorganic contaminants are addressed in the following sections.

#### 5.2.1 Vadose Zone

**5.2.1.1 Anions and Metals in Soil Moisture and Perched Water.** Numerous anions and cations were detected above soil moisture and perched water background concentrations in FY 2004. Some results also exceeded MCLs. The MCLs are not applicable to vadose zone soil-moisture sample results, but are applied by OU 7-13/14 as a means of comparison. Because of the large number of reportable inorganic analysis results, a table listing each result for each lysimeter for each quarter is not included.<sup>h</sup> However, Table 5-5 reports the analytes detected above background and associated concentration ranges observed in FY 2004.

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h. Reportable inorganic analysis results are reported in OU 7-13/14 quarterly reports to the U.S. Department of Energy Idaho Operations Office.



Table 5-5. Positive detections of anions and cations above background in Subsurface Disposal Area vadose zone soil-moisture (lysimeter) samples in FY 2004.

Analyte	Sample Quarter (results greater than background)	Sample Concentration Range (mg/L)	Local Soil-Moisture Background <sup>a</sup> (mg/L)	MCL <sup>b</sup> (mg/L)	Wells with Highest Concentration in FY 2004	Wells with Most Detections Above Background Since 1997
Aluminum	1, 2, 3, 4	<b>0.142–3.31<sup>c</sup></b>	0.140	—	O-4	USGS-92(PW)
Antimony	3	<b>0.031–1.06<sup>d,e</sup></b>	0.031	0.006 <sup>c</sup>	O-2	None
Arsenic	3, 4	<b>0.045–0.79<sup>d,e</sup></b>	0.040	0.010 <sup>c</sup>	O-2	W23, O-7
Barium	1, 2, 3, 4	<b>0.167–0.87<sup>c</sup></b>	0.150	2.00	DE7	DE7
Bromide	1, 2, 3	<b>2.16–12.5<sup>c</sup></b>	2.00	—	I-1S	PA02, TW1, D06,
Cadmium	1, 3	<b>0.005–0.17<sup>d</sup></b>	0.003	0.005	O-4	None
Calcium	1, 2, 3, 4	<b>181–1,640<sup>c</sup></b>	180	—	I-1S	D06, I-1S, USGS-92
Chloride	1, 2, 3	<b>362–4,610<sup>c</sup></b>	340	—	I-1S	USGS-92(PW), PA02, D06, TW1
Chromium	1, 2, 3, 4	<b>0.014–43.2<sup>d</sup></b>	0.013	0.100	O-4	W23, 98-5, O-7
Cobalt	1, 3, 4	<b>0.008–1.09<sup>c</sup></b>	0.004	—	O-4	None
Copper	3	<b>0.242–0.882<sup>c</sup></b>	0.190	1.30	O-2	None
Fluoride	3	<b>2.45–5.74<sup>d</sup></b>	2.00	4.00	PA01	PA01
Iron	1, 2, 3, 4	<b>0.262–471<sup>c</sup></b>	0.210	—	IE7	DE7, USGS-92(PW), IE6
Lead	1, 3	<b>0.026–0.047<sup>d,e</sup></b>	0.016	0.015 <sup>c</sup>	IE6	None
Magnesium	1, 2, 3, 4	<b>69.8–655<sup>c</sup></b>	64.1	—	I-1S	D06, PA02, I-1S, USGS-92(PW)
Manganese	1, 2, 3, 4	<b>1.17–17.3<sup>c</sup></b>	0.99	—	O-4	DE7
Nickel	1, 3, 4	<b>0.223–68.2<sup>d,e</sup></b>	0.17	0.10 <sup>c</sup>	O-2	O-7, D06
Nitrate-N	1, 2	<b>14.8–106<sup>c</sup></b>	11.4	10 <sup>c</sup>	I-2S	PA02, D06, W25, I-2S
Potassium	1, 2, 3, 4	<b>16.1–2,650<sup>c</sup></b>	16	—	D-10(PW)	D06, I-1S, USGS-92 (PW)
Selenium	1, 3, 4	<b>0.020–0.17<sup>d</sup></b>	0.020	0.05	I-1S	D06, PA01
Silver	3, 4	<b>11.3–53.7<sup>c</sup></b>	0.006	—	O-2	O-2

Table 5-5. (continued).

Analyte	Sample Quarter (results greater than background)	Sample Concentration Range (mg/L)	Local Soil-Moisture Background <sup>a</sup> (mg/L)	MCL <sup>b</sup> (mg/L)	Wells with Highest Concentration in FY 2004	Wells with Most Detections Above Background Since 1997
Sodium	1, 2, 3, 4	<b>438–3,200<sup>c</sup></b>	390	—	D06	PA02, D06, W23, PA01, USGS-92(PW)
Sulfate	1, 2, 3	<b>603–4,210<sup>c</sup></b>	596	—	D06	D06, USGS-92(PW)
Vanadium	3, 4	<b>0.0274–0.101<sup>c</sup></b>	0.027	—	O-4	PA01
<p>a. Local soil-moisture background values are the upper concentration ranges obtained from up to 57 soil-moisture samples collected between April 1987 and August 2004 from lysimeter wells located outside of the SDA (i.e., Wells C01, C02, D15, and the O-series wells).</p> <p>b. The MCLs are from the “National Primary Drinking Water Standards” (40 CFR 141) established by the EPA. The MCLs for vadose zone water samples are applicable to perched water, but not to soil-moisture (lysimeter) samples. The MCLs for lysimeter sample results are provided here only as a basis for comparison.</p> <p>c. <b>Black bold font</b> indicates sample concentrations less than the MCL, but exceeding local soil-moisture background concentrations (see Footnote a). Concentration values with a “J” subscript denote that “J” data validation qualifier flags were assigned. The “J” flags were assigned to the nitrate results because the 2-day holding time requirement was exceeded by 1 day. The “J” flags were assigned to the copper results because the serial dilution sample was outside the <math>\pm 10\%</math> difference requirement. The results are usable, but should only be used as estimated quantities.</p> <p>d. <b>Red bold font</b> indicates sample concentrations that exceed the MCL (see Footnote b).</p> <p>e. The MCL was applied, even though its upper limit is lower than the soil-moisture background.</p> <p>EPA = U.S. Environmental Protection Agency  MCL = maximum contaminant level  SDA = Subsurface Disposal Area</p>						

Some of the high metal concentrations observed in FY 2004 appear to be uncharacteristic and abrupt increases; however, in many cases subsequent sample results show concentrations have returned to normal, except in cases where follow-up samples have not been collected yet. Currently, no anions or cations exhibit noticeable concentration trends.

Cation concentrations exceeding MCLs in the vadose zone in FY 2004 were antimony, arsenic, cadmium, chromium, lead, nickel, and selenium. Historically, no consistent detections of antimony, cadmium, or lead were found in the SDA vadose zone; however, arsenic, chromium, nickel, and selenium are often detected above MCLs, but only in specific monitoring wells (see Table 5-5). Arsenic, chromium, and nickel are primarily detected above MCLs in Well O-7 located about 0.8 km (0.25 mi) south of the SDA; however, arsenic is also above the MCL in the SDA at lysimeter location W23:L07. Selenium appears to be associated with only Well D06 near Pad A.

Nickel and chromium are not abundant rock-forming elements, and other natural elements (e.g., aluminum) are low in this sample; therefore, the metals in Lysimeter O7-DL28 do not appear to be suspended solids from natural rock materials. The geochemical behavior of iron, chromium, and nickel are very different. Iron has a higher solubility at low redox potential, chromium is higher in solubility at high redox potential, and nickel is not affected by redox potential. Therefore, the metals do not appear to be related to geochemical conditions in the vadose zone. The ratio of iron to chromium to nickel in this water sample is typical of the ratio of the same metals in stainless steel. Conjecture is that elevated metals in the sample from Lysimeter O7-DL28 are likely the result of stainless steel from lysimeter materials suspended in the sample that were dissolved during sample digestion.

Selenium is often detected above local soil-moisture background concentrations in various lysimeter samples; however, only two lysimeter wells near Pad A (D06 and PA01) exhibit consistent detections with concentrations that are either near or exceed the MCL. Selenium is a small component of the earth's crust and rocks; however, the source of selenium near Pad A has yet to be identified. Selenium is consistently detected in some RWMC aquifer-monitoring wells (see discussion in Section 5.3).

Concentrations of barium, iron, and manganese in deep lysimeter Well DE7 are significantly above local soil-moisture background, and increasing. No regulatory limits are associated with these analytes; therefore, no actions are required. These analytes are mentioned only because previous samples collected from this lysimeter well were discolored and had an unidentifiable organic odor, and a relationship may exist between elevated cation concentrations and unidentified VOCs. Methods to identify the VOCs are ongoing.

**5.2.1.2 Magnesium Chloride Brine.** In FY 2004, lysimeter wells with evidence of brine contamination were consistent with wells where brine was previously identified (Hull and Bishop 2003) (i.e., Wells 8802D, 98-1, D06, I-1S, I-4S, I-4D, O-4, PA02, and TW1). Brine contamination also was detected in Well D15 outside the SDA, and in Wells DE7 and IE7, which were installed in 2003. Wells 98-1 and PA02 have the highest measured chloride concentrations, along with other brine constituents, in the shallow vadose zone with up to 11,000 mg/L. Well 98-1 is located in the southeast corner of the SDA, and Well PA02 is located adjacent to Pad A. In the intermediate vadose zone, chloride levels have reached 5,300 mg/L in Well I-1S. Two perched water wells and two lysimeter wells in the deep region of the vadose zone (i.e., Wells 8802D, USGS-92, DE7, and I-4D) show chloride levels about 90–800 mg/L, which are above the perched water background concentration of 21 mg/L and soil-moisture background of 340 mg/L. Evidence from Lysimeters DE7:DL36 and DE7:DL37 indicate brine has migrated to 115 and 126 m (377 and 413 ft) at the SDA. The chloride concentration at three of these deep locations is greater than 350 mg/L, and the chloride:bromide concentration ratios are around 400:1, indicating the contamination at these depths is indeed magnesium chloride brine (see Table 5-6). Some evidence also suggests the brine may be responsible for some of the elevated anion and cation

Table 5-6. Magnesium chloride brine constituents detected in the deep vadose zone from approximately 200–400 ft in FY 2004.

Brine Well	Date	Chloride (mg/L)	Magnesium (ug/L) <sup>a</sup>	Sulfate (mg/L) <sup>a,b</sup>	Sodium (ug/L) <sup>a</sup>	Potassium (ug/L) <sup>a</sup>	Bromide (mg/L) <sup>a,b,c</sup>	Calcium (ug/L) <sup>a</sup>	Br:Cl Ratio
8802D (220 ft)	05/01/03	<b>770</b>	—	<b>500</b>	—	—	<b>1.80</b>	—	428
	05/06/04	<b>597</b>	<b>80,100</b>	<b>453</b>	<b>401,000</b>	<b>8,540</b>	<b>1.68</b>	<b>95,200</b>	355
USGS-92 (214 ft)	10/29/03	<b>81.7</b>	<b>21,900</b>	<b>64.4</b>	<b>104,000</b>	<b>13,900</b>	0.1 <sub>U</sub>	<b>57,100</b>	—
	02/02/04	<b>88.6</b>	<b>21,100</b>	<b>71.6</b>	<b>97,600</b>	<b>9,440</b>	1.2 <sub>UJ</sub>	<b>49,400</b>	—
	05/06/04	<b>92.7</b>	<b>21,100</b>	<b>68.2</b>	<b>120,000</b>	<b>9,280</b>	0.0 <sub>U</sub>	<b>52,100</b>	—
DE7:DL36 (377 ft)	10/27/03	<b>368</b>	10,400	24	<b>815,000</b>	<b>22,100</b>	<b>4.4</b>	<b>61,700</b>	84
	05/05/04	<b>587</b>	<b>39,100</b>	<b>0.9</b>	<b>159,000</b>	<b>16,100</b>	1.74	<b>190,000</b>	337
	08/30/04	—	51,600	—	139,000	15,700	—	<b>214,000</b>	—
	11/16/04	<b>780</b>	60,000	0.0 <sub>U</sub>	116,000	15,200	<b>2.2</b>	<b>217,000</b>	355
DE7:DL37 (413 ft)	10/27/03	<b>671</b>	<b>84,100</b>	19	143,000	<b>24,800</b>	1.0 <sub>U</sub>	152,000	671
	01/26/04	<b>660</b>	<b>90,000</b>	12	140,000	15,900	<b>2.2</b>	173,000	300
	05/05/04	<b>757</b>	<b>107,000</b>	3.1	157,000	13,900	<b>2.2</b>	<b>181,000</b>	344
	08/31/04	—	<b>113,000</b>	—	157,000	13,400	—	<b>194,000</b>	—
	11/16/04	<b>671</b>	<b>96,700</b>	20	123,000	11,900	<b>2.2</b>	163,000	358
RWMC soil-moisture background ranges:		22–340	11–64.1K	14–596	44–390K	3.8–16K	0.0–2.0	49–180K	—
RWMC aquifer/perched water background ranges:		9–21	13–19K	17–31	8–18K	1–6K	0.00–0.15	19–46K	—

a. **Bold black font** indicates sample concentrations less than the MCL, but exceeding local soil-moisture background concentrations. Local soil-moisture background values are the upper concentration ranges obtained from soil-moisture samples collected between April 1987 and August 2004 from lysimeter wells located outside of the SDA (i.e., Wells C01, C02, D15, R1935, R1936, and the O-series wells).

b. Subscript “U” means the material was analyzed for and was detected at or above the applicable detection limit. However, the associated value was less than five times the highest positive amount in any laboratory blank.

c. Subscript “J” means the material was analyzed for, but was not detected. The associated value is an estimate and may be inaccurate or imprecise. A “UJ” validation flag is not differentiated from the combined action of a “U” and “J” validation flag.

concentrations in the SRPA beneath the RWMC (see Figure 5-4). Though brine constituents are not COCs, the fact that they are so prevalent in the SDA vadose zone—found as deep as 126 m (413 ft) and possibly the aquifer—means that mobile contaminants from buried waste in the SDA (e.g., C-14, Tc-99, I-129, and uranium) may not be far behind.

#### **5.2.1.3 Subsurface Soil Samples Collected While Drilling Lysimeter Well RWMC-2005.**

In April 2004, while drilling lysimeter Well RWMC-2005 in the east end of the SDA (see Figure 2-3), radioactivity above background was detected in the drilling soil returns. Drilling was stopped, and three separate soil samples were collected from these returns. The samples were analyzed for radionuclides, anions, and cations. Six anions and cations were detected with concentrations above background tolerance limits (see Table 5-7). Surficial soil background UTLs are not necessarily applicable to subsurface soils, but are provided here only as a basis for comparison.

### **5.2.2 Aquifer**

Several anions and cations have been detected in concentrations greater than aquifer background values in FY 2004, and one exceeded drinking water MCLs. Lead-analysis results of one sample collected from Well A11A31 in January 2004 exceeded the MCL. Historically, lead has been detected sporadically in this well, and is likely associated with corrosion of the well casing, which is constructed of galvanized steel. Corrosion of the galvanized steel casing also explains why concentrations of aluminum, iron, and zinc also are elevated in this well, because they are all components of galvanized steel.

Elevated concentrations of aluminum, chromium, iron, and sodium were the most widespread and frequently detected metals in FY 2004. Frequently detected anions were chloride and sulfate. Other metals and anions were detected above aquifer background concentrations, but are not widespread and appear unique to some monitoring wells (e.g., arsenic and fluoride are primarily detected in Well M4D, and lead and zinc are mostly associated with Well A11A31). Many of these elevated concentrations may be sampling artifacts, natural elevated concentrations, or constituents of the magnesium chloride dust suppressant. Because of the large number of reportable inorganic analysis results, a table listing each result for each aquifer well for each quarter are not included (see Footnote a). However, Table 8 shows the analytes detected above background and their associated concentration ranges observed in FY 2004.

Many analytes reported in Table 5-8 have historical concentrations above aquifer background levels, but concentrations of these analytes consistently remain below drinking water MCLs and show no observable concentration trends. Only the RWMC monitoring wells exhibiting concentration trends, sudden increases, or other atypical information in FY 2004 are discussed below.

Both filtered and unfiltered samples were collected in FY 2004, and analysis results show some cations exist primarily as suspended solids (i.e., aluminum, iron, lead, and zinc), and other cations are dissolved (i.e., arsenic, chromium, magnesium, nickel, and vanadium). Suspended solids found in the unfiltered samples are most likely from natural sediments in the aquifer or corrosion of well-construction materials; whereas, the dissolved fraction in filtered samples could be contaminants leached from buried waste, chemical constituents of magnesium chloride brine, or minerals dissolved from basalt. However, most reported metals (e.g., aluminum, iron, lead, and zinc) are due to suspended solids in the aquifer or from well-construction materials, except for chromium and magnesium. Most RWMC aquifer-monitoring well samples contain chromium in the dissolved phase and iron and aluminum as suspended solids. This is expected, because under the neutral-to-alkaline pH of the SRPA, and the oxidizing environment, chromium is soluble and iron and aluminum are not.

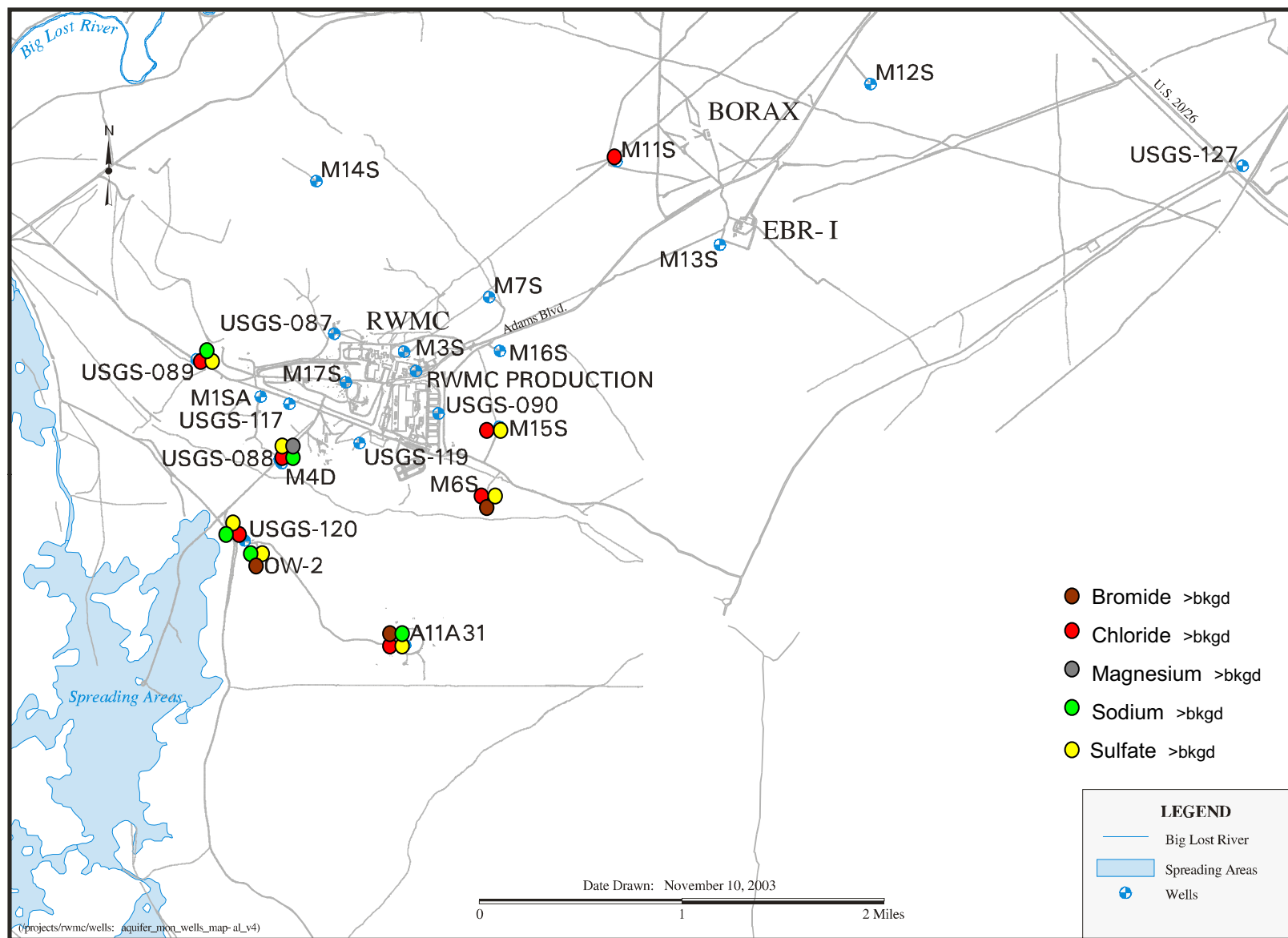


Figure 5-4. Location of the Radioactive Waste Management Complex wells possibly contaminated by magnesium chloride brine or leachates from buried waste.

Table 5-7. Anions and cations detected above upper tolerance limits in soil samples collected from lysimeter installation corehole drilled in the east end of the Subsurface Disposal Area.

Analyte	Sample Date	Sample Location	Sample Result (mg/kg)	MDL (mg/kg)	INL Soil Background UTL <sup>a</sup> (mg/kg)	Soil Hazard Index = 1 <sup>b</sup> (mg/kg)
Arsenic	04/26/04	RWMC-2005	<b>20.2<sup>c</sup></b>	2.39	7.4	23
			<b>21.2<sup>c</sup></b>	2.20	7.4	23
			<b>16.6<sup>c</sup></b>	2.10	7.4	23
Calcium	04/26/04	RWMC-2005	<b>49,400<sup>c</sup></b>	10.9	39,000	NA
			<b>49,100<sup>c</sup></b>	10.0	39,000	NA
			<b>48,600<sup>c</sup></b>	9.58	39,000	NA
Chloride	04/26/04	RWMC-2005	<b>738<sup>c</sup></b>	25	NE	NA
			<b>848<sup>c</sup></b>	24.8	NE	NA
			<b>733<sup>c</sup></b>	24.9	NE	NA
Nitrate-N	04/26/04	RWMC-2005	<b>8.88<sup>c</sup></b>	0.56	NE	NA
Sodium	04/26/04	RWMC-2005	<b>1,470<sup>c</sup></b>	5.54	520	NA
			<b>1,380<sup>c</sup></b>	5.09	520	NA
			<b>1,380<sup>c</sup></b>	4.87	520	NA
Thallium	04/26/04	RWMC-2005	<b>26.8<sub>J</sub><sup>d</sup></b>	9.67	0.68	5.2
			<b>27.7<sub>J</sub><sup>d</sup></b>	8.89	0.68	5.2
			<b>14.6<sub>J</sub><sup>d</sup></b>	8.50	0.68	5.2

a. INL surficial soil background 95% upper tolerance concentration limits for grab samples are not directly applicable to subsurface soils, but are provided here only as a basis for comparison. The surficial soil background tolerance limits were established in 1996 (Rood, Harris, and White 1996).

b. Concentration at which noncarcinogenic health effects can occur.

c. **Black bold font** indicates sample concentrations less than the RBC, but exceeding surficial soil background upper tolerance limits (see Footnote a). Concentration values with a "J" subscript denote that "J" data validation qualifier flags were assigned. The "J" flags were assigned to the thallium results because the percent recovery of the laboratory control sample exceeded the upper control limit. The results are usable, but should be used only as estimated quantities.

d. **Red bold font** indicates sample concentrations greater than a hazard index of 1.

INL = Idaho National Laboratory

MDL = method detection limit

NA = not applicable

NE = not established

RBC = risk-based concentration

UTL = upper 95% tolerance limit with 95% confidence

Table 5-8. Anion and cation concentrations in excess of aquifer background levels or maximum contaminant levels in FY 2004.

Analyte	Sample Quarter (results greater than background)	Sample Concentration Range (µg/L)	Aquifer Background <sup>a</sup> (µg/L)	MCL <sup>b</sup> (µg/L)	Well with Highest Concentration in FY 2004	Wells with Most Detections Above Background Since 1997
Aluminum	1, 2, 3	<b>48.5–337<sup>c</sup></b>	40 <sup>d</sup>	—	A11A31	M17S, M15
Arsenic	2, 3	<b>5.5–11.1<sup>c</sup></b>	5.0	50	M3S	M4D
Bromide	1, 2, 3	<b>170–750<sup>j, e</sup></b>	150	—	A11A31	A11A31
Calcium	3	<b>46,600<sup>c</sup></b>	46,000 <sup>f</sup>	—	M3S	M3S
Chloride	1, 2, 3	<b>21,100–38,900<sup>j, e</sup></b>	21,000 <sup>f</sup>	—	M15S	M6S, M15S, A11A31
Chromium	1, 2, 3	<b>21.3–89.4<sup>c</sup></b>	22 <sup>d</sup>	100	M15S	M1S, M6S, M15S
Fluoride	1, 2, 3	<b>818–835<sup>c</sup></b>	500	4,000	M4D	M4D
Iron	1, 2, 3	<b>93.2–2,970<sup>c</sup></b>	85 <sup>d</sup>	—	M6S	M6S, M15S, OW2
Lead	2	<b>30<sup>f, g</sup></b>	5	15	A11A31	A11A31
Magnesium	1, 2, 3	<b>20,000–22,000<sup>j, e</sup></b>	19,000 <sup>f</sup>	—	M6S	M6S
Manganese	2	<b>17.2<sup>c</sup></b>	15 <sup>d</sup>	—	A11A31	M15S, M17S
Nickel	1, 2, 3	<b>11.0–85.2<sup>c</sup></b>	10 <sup>d</sup>	100	M11S	M6S, M11S
Nitrate-N	2	<b>2020<sup>c</sup></b>	2,000	10,000	M6S	M6S
Potassium	1, 2, 3	<b>19,500–23,300<sup>c</sup></b>	6,000 <sup>d</sup>	—	M4D	M4D
Selenium	1, 2, 3	<b>4.1–9.5<sup>j, e</sup></b>	4 <sup>d</sup>	50	M6S	M6S
Sodium	1, 2, 3	<b>18,400–48,700<sup>c</sup></b>	18,000 <sup>f</sup>	—	M4D	M4D, OW2, A11A31
Sulfate	1, 2, 3	<b>36,600–74,700<sup>j, e</sup></b>	31,000 <sup>f</sup>	—	M6S	M6S, M15S, OW2, A11A31
Vanadium	1, 2, 3	<b>14.1–14.5<sup>c</sup></b>	14.0 <sup>d</sup>	—	M13S	M13S
Zinc	1, 2, 3	<b>265–2,510<sup>c</sup></b>	210 <sup>d</sup>	—	A11A31	A11A31

a. The SRPA background ranges were established in 1992 by the U.S. Geological Survey from samples collected upgradient (i.e., Mud Lake area) and downgradient (i.e., Magic Valley area) of the INL (Knobel, Orr, and Cecil 1992).

b. The MCLs are from “National Primary Drinking Water Standards” (40 CFR 141) established by the EPA.

c. **Black bold font** indicates sample concentrations less than the MCL, but exceeding aquifer background concentrations (see Footnote a). If a background concentration has not been established for a particular analyte, sample results are compared to concentration ranges typically observed in the aquifer at or near the INL (see Footnote e).



Table 5-8. (continued).

Analyte	Sample Quarter (results greater than background)	Sample Concentration Range (µg/L)	Aquifer Background <sup>a</sup> (µg/L)	MCL <sup>b</sup> (µg/L)	Well with Highest Concentration in FY 2004	Wells with Most Detections Above Background Since 1997
<p>d. Concentration ranges of various analytes in the SRPA at or near the INL were established in 1999 by the USGS from samples collected from 39 locations at or near the vicinity of the INL and Eastern Snake River Plain (Knobel et al. 1999). The aquifer concentration range shown for chromium, iron and zinc do not include atypical concentrations measured near the RTC (i.e., 210, 210, and 420 µg/L, respectively). In addition, the potassium and sodium concentration ranges do not include atypical concentrations measured in monitoring wells located a few miles north of the INL and near the INTEC.</p> <p>e. Established USGS concentration ranges in the SRPA at or near INL for calcium, chloride, magnesium, and sodium are too high for assessing whether magnesium chloride brine from the SDA has migrated to the SRPA beneath the RWMC. To fine tune the concentration ranges observed around the INL, additional aquifer well data from the 1999 plutonium background study and the 2003 upgradient study were combined with the 1999 USGS data. Upper concentration ranges are based on the mean concentration plus the standard deviation of the mean.</p> <p>f. Concentration ranges with a “J” subscript denote that “J” data qualifier flags were assigned to one or more results during FY 2004. To know which monitoring well, sampling quarter, sample result, and reason why a “J” qualifier flag was assigned, refer to OU 7-13/14 FY 2004 quarterly letter reports to the U.S. Department of Energy Idaho Operations Office (i.e., JMS-32-04, JMS-62-04, JMS-98-04, and AC-63-04). All “J” flagged results are usable, but should be used only as estimated quantities.</p> <p>g. <b>Bold red font</b> indicates sample sample concentrations that exceed the MCL (see Footnote b).</p>						

EPA = U.S. Environmental Protection Agency  
FY = fiscal year  
INL = Idaho National Laboratory  
INTEC = Idaho Nuclear Technology and Engineering Center  
MCL = maximum contaminant level  
RTC = Reactor Technology Complex  
SDA = Subsurface Disposal Area  
SRPA = Snake River Plain Aquifer  
USGS = U.S. Geological Survey

— = not established or not applicable

Many chromium concentrations in the aquifer beneath the RWMC are significantly above the maximum concentration range found in the SRPA around the INL. Total chromium concentrations in FY 2004 ranged from about 5 pCi/L in Well M4D to 89 pCi/L in Well M15S. Total chromium includes contributions from dissolved and solid chromium as well as chromium in various oxidation states (e.g.,  $\text{Cr}^{3+}$  and  $\text{Cr}^{6+}$ ). Total chromium concentrations in four RWMC monitoring wells (i.e., Wells M1SA, M6S, M11S, and M15S) historically exceed concentrations typically detected in the SRPA around the INL (1–22  $\mu\text{g/L}$ ), as determined from data published by Knobel et al. (1999), which excludes atypically high concentrations measured around the RTC. Wells M1SA and M6S have shown a gradually increasing concentration trend over the past 11 years, and Wells M11S and M15S began their upward trend in the past couple of years (see Figure 5-5). The USGS monitoring wells south of the SDA (Wells USGS-88, -89, and -119) also have elevated concentrations of chromium. Even though Wells USGS-088, USGS-089, and USGS-119 have not been analyzed recently for chromium (1996 is most recent), it is conjectured that the chromium levels in those wells would still be elevated and roughly comparable to these measured in the WAG 7 aquifer-monitoring wells located on the south and southeast side of the RWMC. Most of the wells with elevated chromium concentrations are located immediately south and southeast of the RWMC (see Figure 5-6), except for Well M11S, which is about 3 km (2 mi) upgradient of the RWMC. This pattern of chromium occurrence is consistent with other elevated analytes (i.e., bromide, chloride, magnesium, sodium, sulfate) in these particular wells; this would be expected if contaminants were leaching from the SDA and accumulating in wells to the south and southeast due to the presence of a low flow or low permeability zone (Wylie and Hubbell 1994).

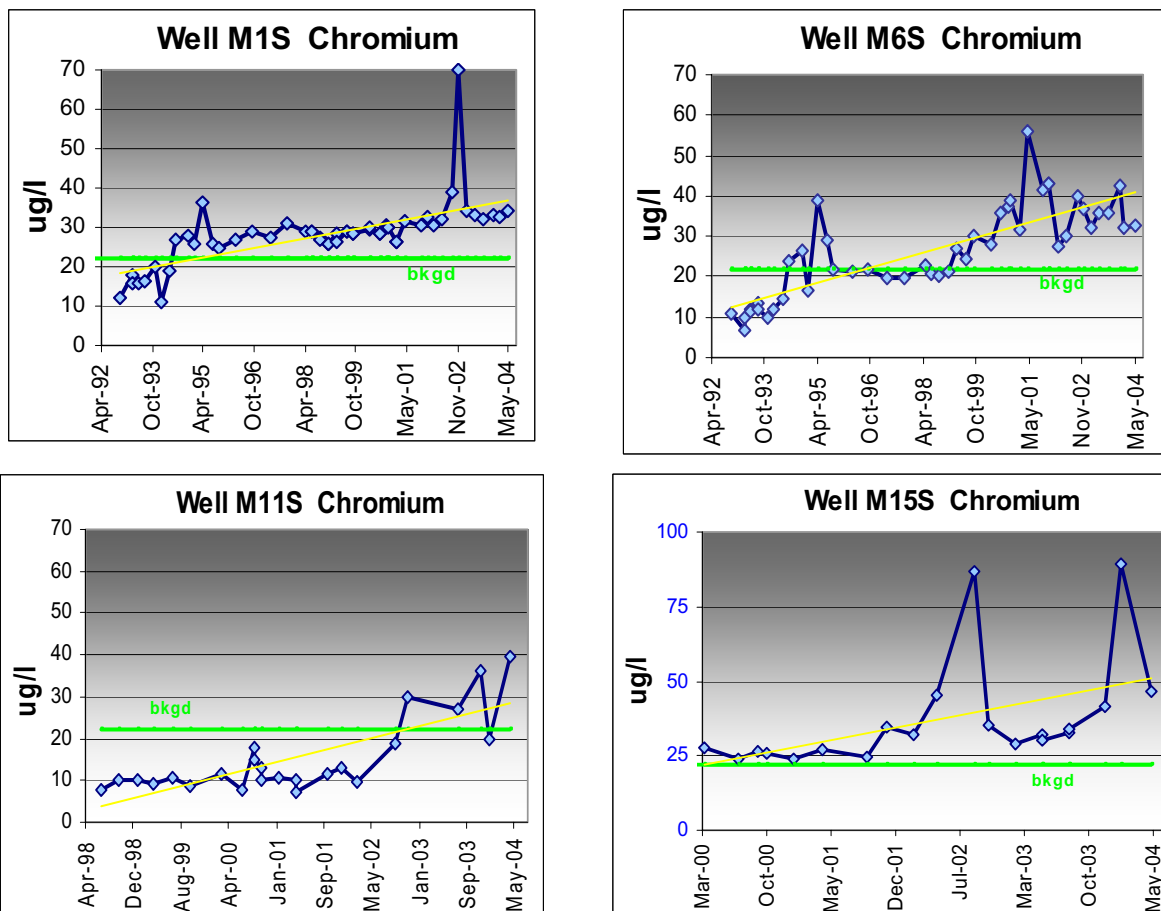


Figure 5-5. Radioactive Waste Management Complex aquifer-monitoring wells with increasing chromium concentrations.

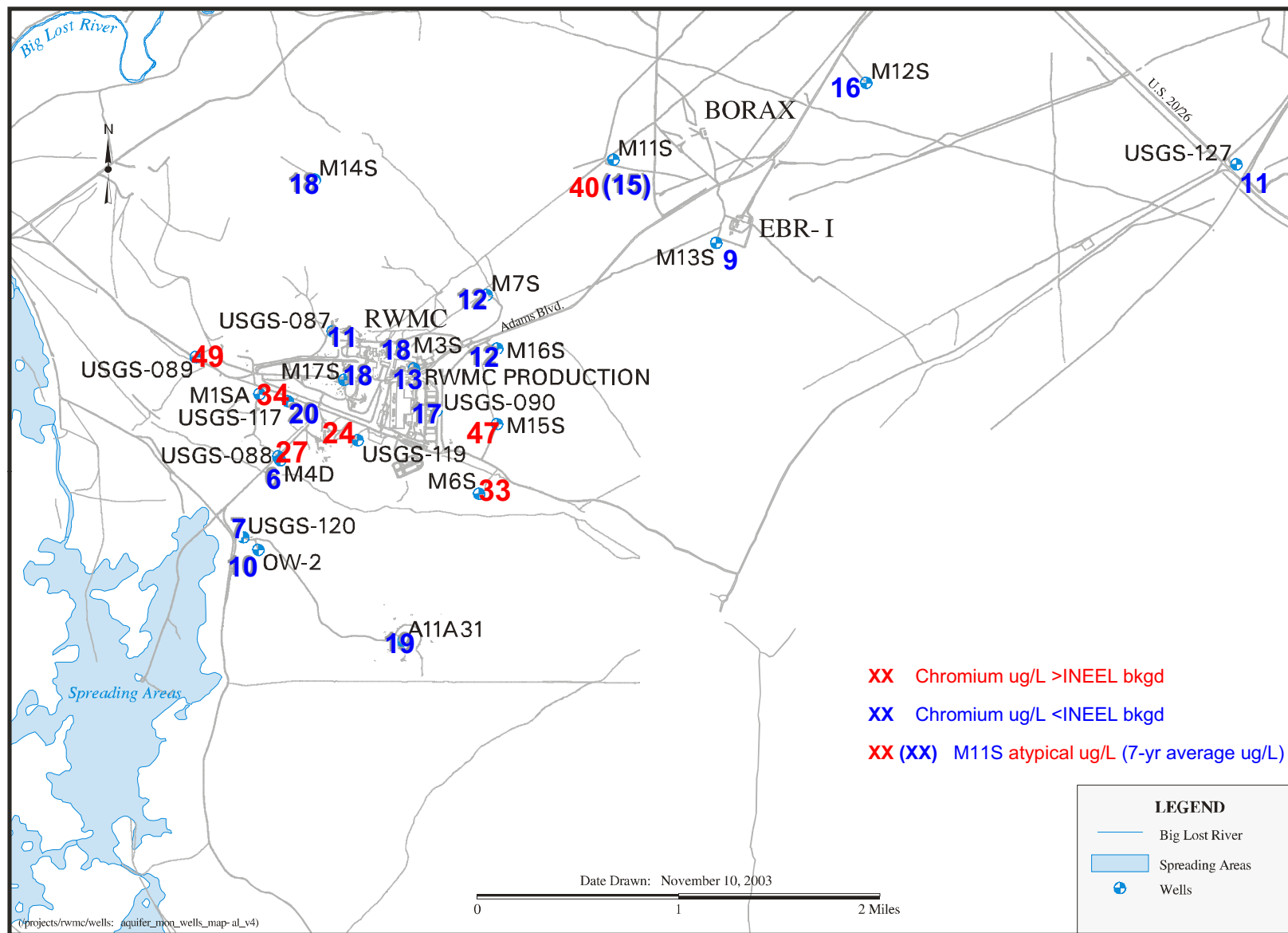


Figure 5-6. Chromium concentrations in wells at the Radioactive Waste Management Complex.

Chromium in Well M11S contains a significant fraction of suspended solids, indicating that the chromium in this well is likely associated with corrosion of the stainless steel well-construction materials. Chromium in Wells M1SA, M6S, and M15S are mostly in the dissolved phase indicating chromium could be from high natural abundance in basaltic formations beneath the RWMC or from SDA waste leachates. Well M15S also has a substantial fraction of chromium that exists as a suspended solid, suggesting corrosion of well-construction materials. Concentrations of dissolved chromium in the SRPA, upgradient and downgradient of the INL, range from 1–50 ug/L (Knobel, Orr, and Cecil 1992); whereas, concentrations on or near the INL range from 1–190 ug/L, with the highest concentrations near the RTC (Knobel et al. 1999). Whether elevated levels of chromium in wells located at the south-southeast side of the RWMC are from the SDA, RTC, or natural occurrences has not been absolutely determined. Chromium concentrations within a 2-km (1-mi) radius of the RWMC are generally higher than concentrations farther away than 2 km (1 mi) (see Figure 5-7). Further sampling, analysis, and data evaluation are necessary to positively determine whether elevated chromium concentrations in the aquifer near the RWMC are from waste leachates, upgradient influences, or natural phenomena.

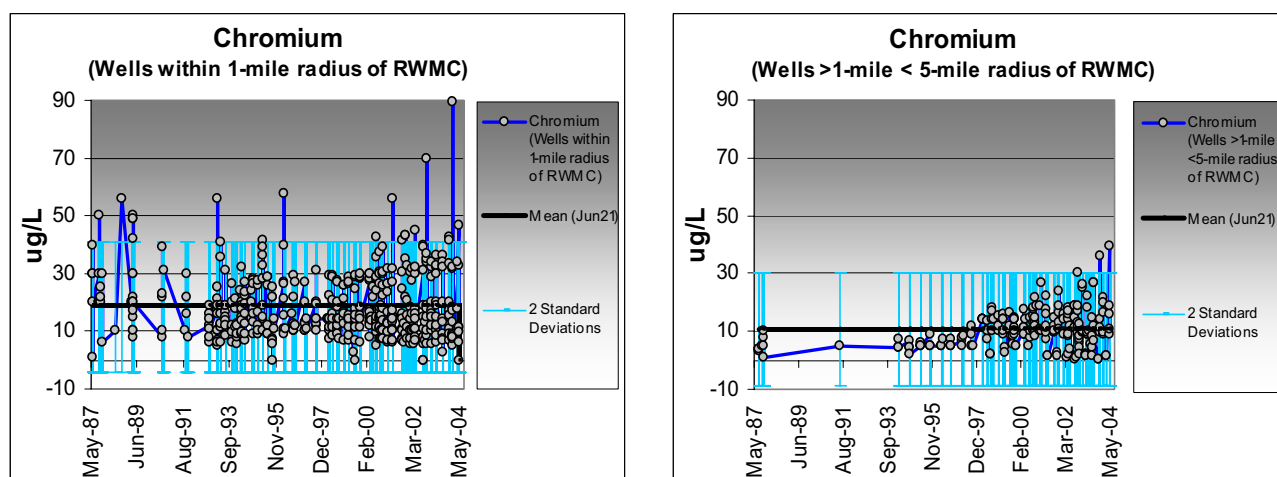


Figure 5-7. Chromium concentrations within a 1-mi radius are generally higher than concentrations within 1–5-mi radius of the Radioactive Waste Management Complex.

In addition to chromium, other metals (magnesium and sodium) and anions (bromide, chloride, and sulfates) are detected at elevated concentrations in the aquifer around the RWMC that are exhibiting a spatial pattern similar to chromium (see Figure 5-4). Many of these metals and anions appear to be characteristic of magnesium chloride brine, but could also be leachates from buried waste, or could possibly be groundwater contaminants from the RTC (e.g., sulfates) or INTEC (e.g., chlorides).

Upgradient influences are unlikely because H-3 (common to both facilities) was not detected in the affected RWMC wells. Evidence suggests that the SDA is the source of elevated bromide, chloride, magnesium, sodium, and sulfate in the SRPA south-southeast of the RWMC. However, brine may not be entirely responsible for these contaminants, because high chlorides, sodium, and sulfates have been measured in nearby Wells USGS-88 and USGS-89 since 1977, long before brine was applied to roads in the SDA. Conversely, other USGS wells in this area with a 17-year sampling history (i.e., Wells USGS-117 and USGS-119) do not show elevated concentrations of these anions or cations. Aquifer-sample chemistry in this area of the RWMC should be somewhat comparable, because screened intervals of each well overlap, and pump depths are within a 20-m (65-ft) depth interval of each other, except for Wells M11S and M15S. Even though most well samples in this area are collected at similar depths, the anion and cation chemistry, including their ratios, are very different. Hydrologic or geologic

components, which are likely in this area, affect the chemistry. Further sampling, analysis, and data evaluation are necessary to positively determine whether observations in the aquifer south–southeast of the RWMC are from brine, waste leachates, or natural phenomena.

Analyte concentrations in Well M4D are unlike all other RWMC aquifer-monitoring wells. Potassium, sodium, and gross beta concentrations are about six times higher than in other wells, and arsenic is approximately two times higher; whereas, calcium and magnesium are approximately five times lower, and naturally occurring uranium concentrations are approximately two times lower than other RWMC wells. Sodium has a slightly increasing concentration trend; whereas, the other analytes show a relatively flat or slightly decreasing trend. Well M4D is much deeper than other RWMC aquifer-monitoring wells (i.e., 117 vs. about 198 m [838 vs. about 650 ft]), and the difference in chemistry between this well and the other RWMC wells suggests that groundwater at deep levels is isolated from the shallower groundwater.

### **5.2.3 Summary of Other Inorganic Contaminants**

The source of some anions and cations detected above background in RWMC aquifer and vadose zone soil, and soil-moisture samples cannot be absolutely determined at this time. Many of these anions and cations are of concern because they could be contaminants from buried waste or chemical components of magnesium chloride brine. The constituents of brine do not pose a serious risk to human health or the environment. Brine constituents may be useful as chemical tracers indicative of contaminant migration in the vadose zone beneath the SDA; however, they may promote corrosion of waste containers.

Chromium concentrations in most RWMC aquifer-monitoring wells are consistent with levels typically observed around the INL (i.e., 1-22 µg/L). Nonetheless, the RWMC chromium concentrations in Wells M1S, M6S, M11S, and M15S are above SRPA background at the INL and increasing. The chromium trend for these wells, as well as elevated chloride and sulfate in Wells M6S, M11S, M15S, and A11A31, continue to be of concern.

The location of aquifer-monitoring wells with elevated concentrations of anions and some metals, especially chromium, are all on the south–southeast side of the RWMC; this may support the hypothesis that a low-permeability zone lies along the south side of the SDA.



## 6. GEOHYDROLOGIC PROPERTIES OF INTERBED CORES

### 6.1 Geological Properties

Information presented in this section presents results of a study performed by Laurence C. Hull (INL), Joel M. Hubbell (INL), and Cheryl A. Whitaker (ICP). Samples of interbed material were collected from five wells (see Figure 2-6) in the SDA. Only the C-D interbed was sampled, because the limited material available from the B-C interbed was prioritized for radionuclide analysis. Samples were analyzed for exchangeable cations, extractable iron, aluminum and magnesium, cation exchange capacity, and clay-specific and quantitative X-ray diffraction. Core samples were obtained from stored core material initially collected in the SDA by the OCVZ Project (OU 7-08) between November 2002 and March 2003.

Analysis results indicate that mineral composition of the C-D interbed is about 75 percent quartz, 20 percent feldspar minerals, and 5 percent layered silicates (see Table 6-1). The clay mineralogy averages about equal amounts of smectite, illite, and kaolinite, with a small percent of chlorite (see Table 6-2). Extractable oxides, surface area, and cations are listed in Tables 6-3 and 6-4, and results are generally comparable to those reported in previous.

Table 6-1. Bulk mineralogy composition of interbed sediments.

Well Name	Well ID	Sample Depth (ft bls)	Quartz SiO <sub>2</sub> (wt%)	Anorthoclase (Na,K)AlSi <sub>3</sub> O <sub>8</sub> (wt%)	Albite NaAlSi <sub>3</sub> O <sub>8</sub> (wt%)	Muscovite KMgAlSi <sub>4</sub> O <sub>10</sub> (OH) <sub>2</sub> (wt%)	Saponite Mg <sub>3</sub> (Si,Al) <sub>4</sub> O <sub>10</sub> (OH) <sub>2</sub> • 4H <sub>2</sub> O (wt%)	AlPO <sub>4</sub> • H <sub>2</sub> O (wt%)
RWMC-1810	DE-3	243.2	81	7	3	7	2	0
RWMC-1813	DE-4	232.7	75	11	8	5	2	0
RWMC-1813	DE-4	239.3	72	9	12	6	2	0
RWMC-1816	DE-6	240	73	15	7	2	2	0
RWMC-1819	DE-7	242.4	75	9	5	8	3	0
RWMC-1819	DE-7	247.3	74	8	9	9	1	0
RWMC-1819	DE-7	248.7	72	10	10	6	2	0
RWMC-1822	DE-8	232.5	68	11	14	1	1	4
RWMC-1822	DE-8	240.5	75	15	0	8	2	0
Average			73.9	10.6	7.6	5.8	1.9	0.4

Table 6-2. Clay mineralogy of interbed sediments.

Well Name	Well ID	Sample Depth (ft bls)	Smectite (wt%)	Illite (wt%)	Kaolinite (wt%)	Chlorite (wt%)
RWMC-1810	DE-3	243.2	31	28	35	6
RWMC-1813	DE-4	232.7	48	28	19	4
RWMC-1813	DE-4	239.3	24	26	45	5
RWMC-1816	DE-6	240	57	18	22	3
RWMC-1819	DE-7	242.4	27	30	39	3
RWMC-1819	DE-7	247.3	0	51	41	7
RWMC-1819	DE-7	248.7	39	25	33	3
RWMC-1822	DE-8	232.5	44	32	21	4
RWMC-1822	DE-8	240.5	29	29	35	7
Average			33.2	29.7	32.2	4.7

Table 6-3. Surface area and extractable oxides of interbed sediments.

Well Name	Well ID	Sample Depth (ft bls)	Surface Area (m <sup>2</sup> /g)	SiO <sub>2</sub> (mg/g as oxide)	Al <sub>2</sub> O <sub>3</sub> (mg/g as oxide)	Fe <sub>2</sub> O <sub>3</sub> (mg/g as oxide)	MnO <sub>2</sub> (mg/g as oxide)
RWMC-1810	DE-3	243.2	49.8	5.76	2.87	14.6	0.262
RWMC-1813	DE-4	232.7	31.2	6.4	2.6	17.1	0.218
RWMC-1813	DE-4	239.3	40.8	5.8	2.62	16.3	0.2
RWMC-1816	DE-6	240	17.7	4.12	1.72	12.0	0.138
RWMC-1819	DE-7	242.4	48.1	5.76	2.71	15.4	0.244
RWMC-1819	DE-7	247.3	57.0	4.47	2.51	13.0	0.215
RWMC-1819	DE-7	248.7	50.2	5.09	2.67	10.8	0.254
RWMC-1822	DE-8	232.5	11.7	3.24	1.32	10.8	0.148
RWMC-1822	DE-8	240.5	56.1	5.26	3.0	14.0	0.24

Table 6-4. Exchangeable cations of interbed sediments.

Well Name	Well ID	Sample Depth (ft bls)	Exchange Calcium (meq/100 g)	Exchange Potassium (meq/100 g)	Exchange Magnesium (meq/100 g)	Exchange Sodium (meq/100 g)	Exchange Strontium (meq/100 g)	Sum of Exchange Cations (meq/100 g)	Cation Exchange Capacity (meq/100 g)
RWMC-1810	DE-3	243.2	16.6	0.967	6.05	0.271	0.0301	23.9	22
RWMC-1813	DE-4	232.7	32.2	0.612	4.93	0.253	0.0335	38.0	16.3
RWMC-1813	DE-4	239.3	15.7	0.669	6.09	0.239	0.0264	22.7	12.5
RWMC-1816	DE-6	240	—	—	—	—	—	—	—
RWMC-1819	DE-7	242.4	18.4	0.73	6.72	0.246	0.0302	26.2	23.1
RWMC-1819	DE-7	247.3	19	0.818	6.79	0.22	0.0286	26.9	23.3
RWMC-1819	DE-7	248.7	16.5	0.891	6.15	0.267	0.0273	23.8	21.1
RWMC-1822	DE-8	232.5	25.8	0.31	2.3	0.315	0.0264	28.8	5.4
RWMC-1822	DE-8	240.5	18.1	0.9	6.94	0.388	0.0340	26.3	23.4

These results were compared with previous geochemical analyses performed on core and interbed material at the RWMC using statistical comparison methods, and most parameters were generally comparable. Even though the  $K_d$  predictor parameters were comparable to previous values, continuity within the interbeds is not proven; however, results do suggest that geochemical conditions are continuous. These data reinforce the assumption used in the TETRAD model that  $K_d$  values are continuous across the SDA. Important variables for predicting uranium and neptunium  $K_d$  values were determined to be the sum of exchangeable cations (cation exchange capacity in meq/100 g), exchangeable calcium and magnesium (meq/100 g), extractable iron oxides (mg/g sediment), illite clay fraction, extractable manganese oxides (mg/g sediment), silt, and smectite clay fraction (Leecaster and Hull 2004).

## 6.2 Hydrologic Properties

Samples for analysis of hydrologic properties were obtained from the uppermost section of the core interval nearest the basalt layer above the interbed and from a distinct coarse-to-fine sediment interface. Only samples from the C-D interbed were analyzed for hydrologic properties. Samples were analyzed for saturated hydraulic conductivity, porosity, moisture content, initial volumetric water content, and dry bulk density. Analysis results of the interbed sediments are listed in Table 6-5.



Table 6-5. Hydrologic properties of interbed sediments.

Well Name	Well ID	Sample Depth (ft bls)	Bulk Density (g/cm <sup>3</sup> )	Moisture Content (%)	Total Porosity (%)	Sat. Hydraulic Conductivity (cm/second)
RWMC-1810	DE-3	243.3	1.67	17.3	29.8	1.30E-03
RWMC-1813	DE-4	233.1	1.59	25.7	34.6	2.62E-04
RWMC-1813	DE-4	239.3	1.64	22.9	31.1	7.27E-05
RWMC-1816	DE-6	240.2	1.67	19.4	30.7	5.13E-04
RWMC-1819	DE-7	242.5	1.61	20.9	32.1	7.99E-04
RWMC-1819	DE-7	247.5	1.64	18.8	31.7	1.32E-03
RWMC-1819	DE-7	249	1.79	18.1	23.2	4.54E-04
RWMC-1822	DE-8	233.4	1.60	4.4	35.2	8.33E-02
RWMC-1822	DE-8	240.7	1.50	17.9	37.2	3.04E-03
RWMC-1822	DE-8	242	1.82	12.6	21.6	1.29E-05

Porosity and hydraulic conductivity were measured in 10 samples from five new locations in 2004. New porosity and permeability results were compared with predicted values. Table 6-6 lists the measured values of the new wells, previous values (2002) from the nearest well, predicted values, and prediction intervals.

Table 6-6. Comparison of new C-D interbed core porosity and permeability to model predictions and near-well values.

Well Name	Sample Depth (ft bls)	Observed porosity (%)	Predicted Porosity (%)	Prediction interval (%)	Closest observed porosity (%)	Observed permeability (mD)	Predicted permeability (mD)	Prediction interval (mD)	Closest observed permeability (mD)
RWMC-1810	243.3	29.8	45.20	37.4–53.0	43.02	737.36	476.18	169.3–783.0	321.27
RWMC-1813	233.1	34.6	30.98	26.6–35.3	29.88	271.22	290.74	0–616.1	3.00
RWMC-1813	239.3	31.1				75.26			
RWMC-1816	240.2	30.7	42.10	35.1–49.1	44.2	39.89	504.63	145.9–863.3	339.23
RWMC-1819	242.5	32.1				827.12			
RWMC-1819	247.5	31.7	47.07	43.6–50.6	48.86	1,366.46	230.34	0–524.0	10.80
RWMC-1819	249	23.2				469.98			
RWMC-1822	233.4	35.2				86,231.88			
RWMC-1822	240.7	37.2	48.43	38.4–58.5	43.02	3,147.00	498.98	161.6–836.4	321.27
RWMC-1822	242	21.6				13.35			

All porosity values were less than those measured in nearby wells and less than the lower prediction interval, except for results from Well RWMC-1813 DE-4. Eight of the 10 permeability values were greater than those measured in nearby wells, and six were outside the prediction intervals. Model predictions were not very close to the newly measured values. Although the new data do not agree well with the model, the data agree better with the model predictions than with the overall median. Therefore, it is concluded that modeling the spatial distribution of permeability is an improvement over predicting an overall mean or median for the whole area.

### 6.3 Summary of Interbed Core Study

Newly measured hydrologic properties for the interbeds beneath the RWMC were obtained and compared to parameter values used in the TETRAD fate and transport model for OU 7-13/14. Geochemical properties were evaluated to test the assumption used in the TETRAD model of continuous, constant  $K_d$  values in interbeds for radionuclide retardation. Measured radionuclide concentrations are compared to predicted radionuclide migration.

Geochemical and material properties (i.e., exchangeable cations; cation exchange capacity; extractable iron, aluminum, and manganese; surface area; clay and quantitative X-ray diffraction) were analyzed and the results compared with previous interbed analysis using laboratory, calculated, and statistical methods. Previous work by Leecaster and Hull (2004) provided properties results and statistical analysis of important material properties predictors of  $K_d$ . The expected range of these properties was compared with results from this sampling effort. Geochemical and material properties for current sampling are within the expected range for previous sampling, with the exception of slightly elevated oxides of aluminum, which are not identified in previous work as a significant predictor of  $K_d$ . The comparability of the new geochemical results to previous results supports the assumption used in the TETRAD model that  $K_d$  values are continuous in interbeds across the SDA.

Hydrologic properties were analyzed including saturated hydraulic conductivity, porosity, initial volumetric water content; dry bulk density; and grain size analysis. The results for porosity and permeability were compared with predicted values based on previous interbed analyses. New results were within the range exhibited in previous hydrologic properties sampling. Statistical analysis of results for new permeability and porosity are either within or below the model predictions for these properties in 60 percent of the samples. Small sample size makes analysis of results more uncertain; however, given that condition, the data do not suggest significant bias in the model.

## 7. SUMMARY

Soil moisture, soil gas, perched water, and the aquifer are monitored around the RWMC to meet a variety of INL needs. Monitoring data were summarized for radionuclide and nonradionuclide contaminants for the shallow (0–11 m [0–35 ft]), intermediate (11–43 m [35–140 ft]), and deep (greater than 43 m [140 ft]) vadose zone and for the perched water and the aquifer. Aquifer samples are collected on a semiannual basis.

The environmental monitoring program at the RWMC serves multiple needs. This report focuses on the needs of two specific activities: (1) continued operation of the Low-Level Waste Disposal Facility and (2) evaluation of the nature and extent of contamination. Although many objectives are similar for the two projects, there are a number of differences in COCs and other specific needs. Thus, separate summaries of data presented in the report are provided in the following two sections in the context of the different needs.

### 7.1 Summary in the Context of the Comprehensive Environmental Response, Compensation, and Liability Act

Results from the waste zone, vadose zone, and aquifer monitoring indicate that some contaminants are migrating out of the waste zone and into the vadose zone; however, data about the aquifer are inconclusive. Tritium was detected in the vadose zone and aquifer beneath the RWMC, but significant detections also occurred upgradient of the RWMC. It is speculated that tritium is from upgradient facilities, primarily RTC; however, it is also likely that some of the tritium beneath the RWMC comes from sources in the SDA. Uranium is regularly detected above background concentrations in the shallow- and intermediate-depth lysimeters around Pad A, Pit 5, and the western end of SDA. In the deep vadose zone, anthropogenic uranium was detected at one monitoring location in Pit 5 at 69 m (227 ft). Uranium detections in aquifer wells located around the RWMC are representative of natural uranium; however, indications of very low concentrations of anthropogenic uranium were found in two upgradient RWMC wells. Brine contaminants continue to migrate through the SDA vadose zone, as detections in the intermediate and deep regions of the SDA vadose zone (i.e., 11–43 m [35–140 ft] and deeper than 43 m [140 ft]) are becoming more frequent and widespread. This FY, brine was detected in the vadose zone at depths of 115 and 126 m (377 and 413 ft), and there were some indications of brine possibly reaching the aquifer beneath the RWMC. These data appear to warrant further investigation for use as modeling calibration targets or model validation and to assess potential future impacts to the aquifer.

Other results include the following:

- Carbon tetrachloride, toluene, and trichloroethene are affecting the aquifer beneath the RWMC. Affected aquifer wells are generally located east and southeast of the RWMC.
- Concentration trends of  $\text{CCl}_4$  in many RWMC aquifer wells appear to be stabilizing, but continue to be detected at concentrations around the MCL in Wells M7S and M16S.
- Chromium concentrations in aquifer Wells M1S, M6S, M11S, and M15S are significantly above aquifer background levels, and have evident concentration trends. Because chromium concentrations in Well M15S fluctuate more than other wells, it is likely that the MCL could be exceeded with future concentration spikes.
- A U-235 concentration trend may be developing in upgradient aquifer Wells M12S and M13S.

- Chemical constituents of magnesium chloride brine have been detected at the 126-m (413-ft) depth in the vadose zone, and may have been detected in aquifer wells east and southeast of the RWMC.
- Uranium concentrations in a few isolated areas of the SDA, between the 0- and 43-m (0- and 140-ft) depth interval, and one at 69 m (227 ft), are significantly elevated, above 1E-05 RBCs, and continue to show both concentration trends and isotopic ratio trends. Some lysimeters have trends indicative of anthropogenic uranium slightly enriched in U-235; however, recent data at some locations show isotopic ratio trends changing in a direction more indicative of natural uranium.
- Technetium-99 is consistently detected at depths to 27 m (88 ft) in Lysimeter Well D06, by Pad A, and Well W23, at the west end of the SDA. The concentration associated with Well D06 is increasing and approaching the aquifer 1E-05 RBC.
- Significant nitrate concentration trends are occurring in two locations in the vadose zone at depths around 30 m (100 ft). The trends are associated with Lysimeter Wells PA02 and I-2S, which are located by Pad A and in the west end of the SDA, respectively.
- Low-level tritium detections in the vadose zone are becoming more widespread and fairly consistent, especially in Wells I-2S, I-2D, and I-3S, and detections are occurring more frequently in Perched Water Well USGS-92. The major source of tritium is likely from beryllium blocks buried in the SDA. The effect that grouting had on tritium is unknown, but will be determined over time.
- Air concentration data from beryllium-block monitoring show consistent annual fluctuations of tritium and a total release of 2 Ci for FY 2004, but with no obvious long-term trend in air concentrations.
- Carbon-14 concentrations around the beryllium blocks are substantially higher than C-14 concentrations near the activated steel or low-level waste disposals, as expected.

Locations of contaminants consistently detected at concentrations above background are shown on Figures 7-1 and 7-2 for the vadose zone and aquifer, respectively. Only monitoring wells showing three or more detections within the past 7 years, one or more of which were recent (i.e., FY 2004) detections, are included on the two figures.

## **7.2 Summary in the Context of Low-Level Waste Disposal**

Chapter IV of DOE Order 435.1 requires that the results of PA and CA modeling be used to design an environmental monitoring program for the disposal facility. The monitoring results are to be used to verify modeling assumptions, confirm that the model adequately represents actual conditions, and demonstrate compliance with RWMC performance objectives. Required data streams for the RWMC PA and CA monitoring program are identified in the PA and CA monitoring program description (McCarthy, Seitz, and Ritter 2001). Most of the required information can be gathered from results of the ongoing INL monitoring programs, but several new monitoring efforts have been initiated to characterize the migration of radionuclides in surface sediment near specific types of waste. Results of the monitoring are discussed in the following sections.

A comparison of the FY 2004 monitoring results with FY 2004 action levels from the PA is made in the annual PA and CA review (Parsons, Seitz, and Keck 2005). The action levels are concentrations predicted at different locations in the vadose zone and aquifer based on modeling conducted for the existing PA and CA. If measured concentrations are below the action levels, then the model

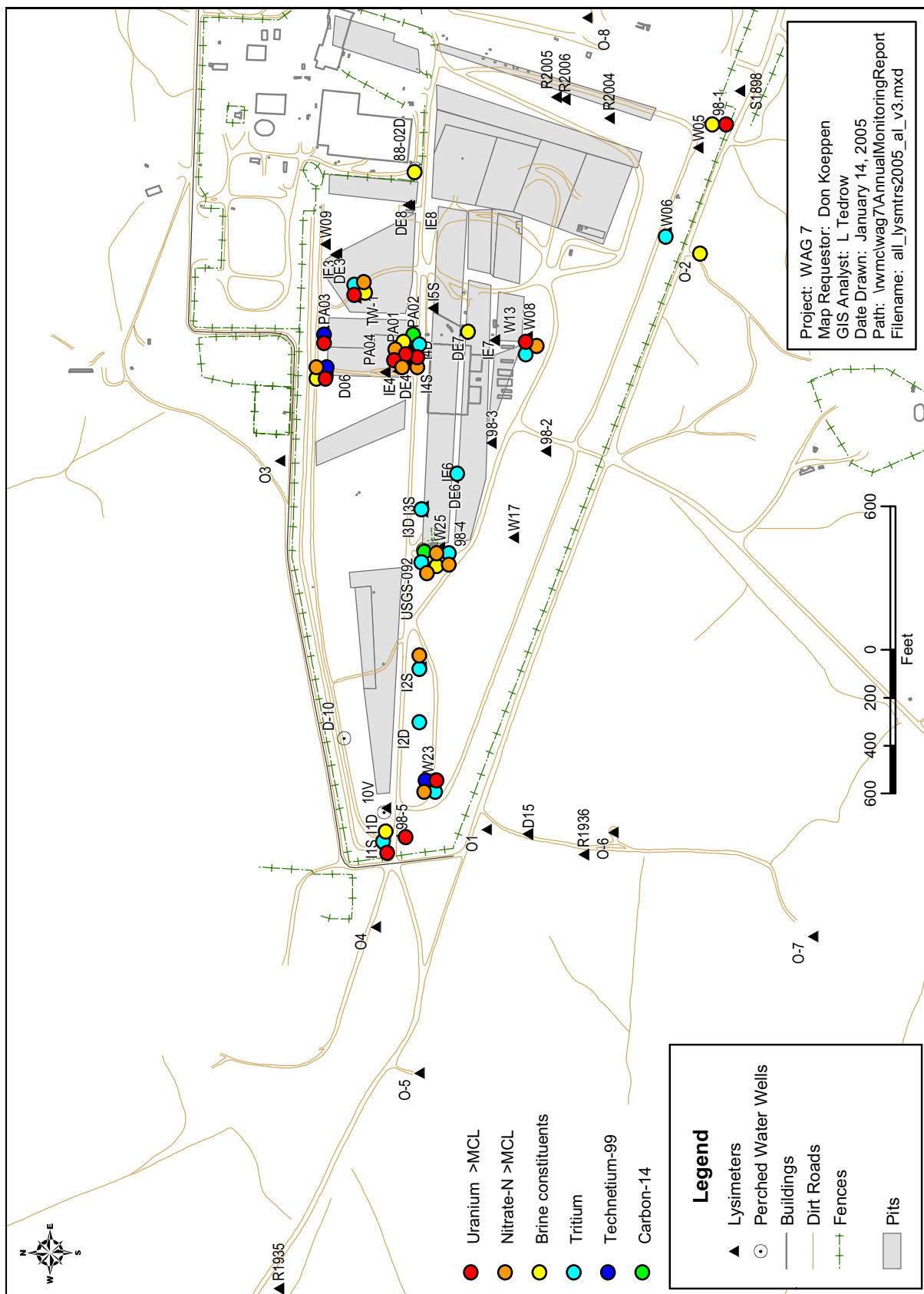


Figure 7-1. Current status of recurrently detected contaminants and their locations within the Subsurface Disposal Area.

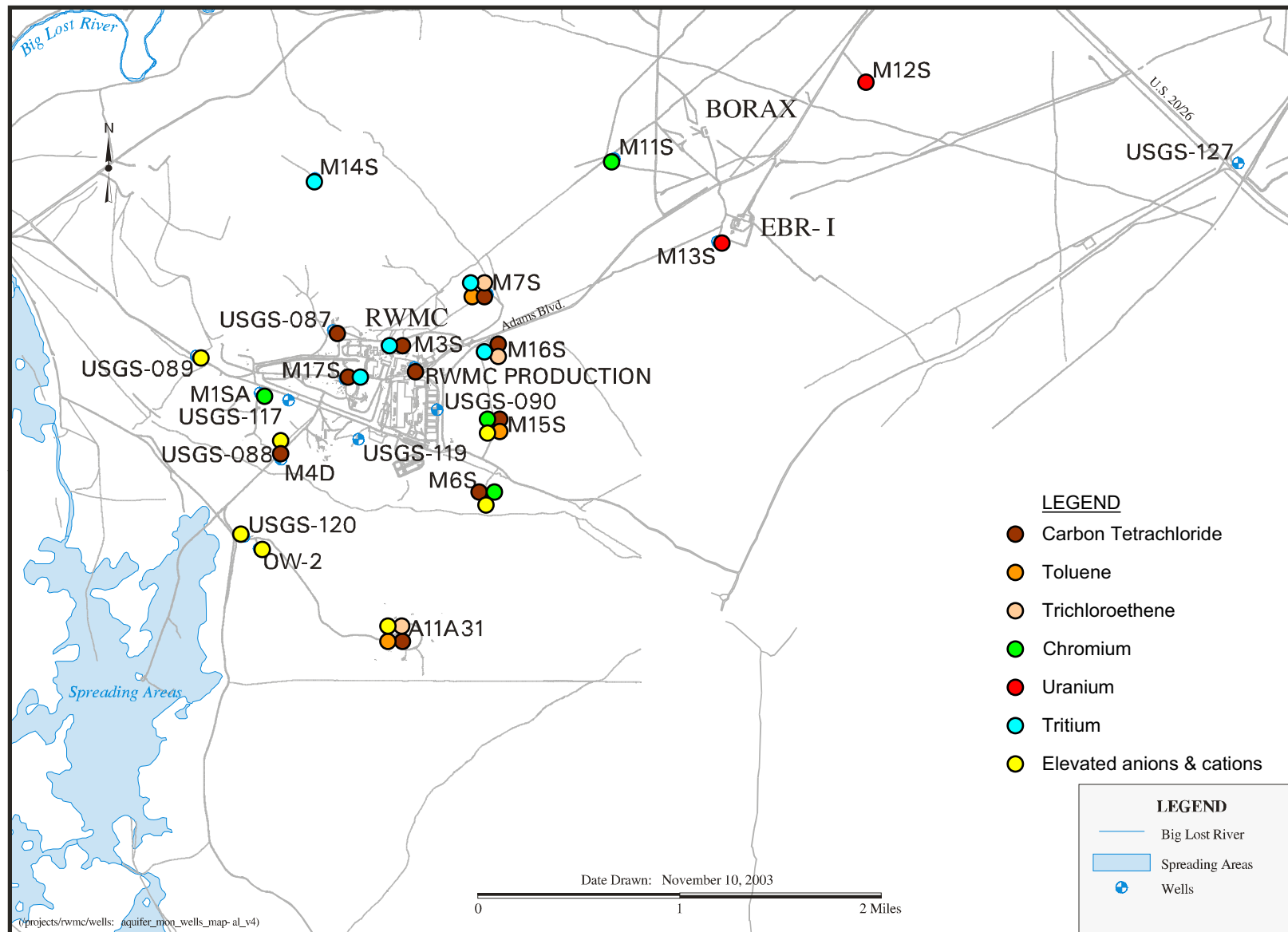


Figure 7-2. Current status of contaminants and their locations in Radioactive Waste Management Complex aquifer.

conclusions about compliance remain valid. The summary information in this report (see Tables 3-9, 3-10, 3-12, 3-13, 3-19, 3-20, 3-21, 3-22, 3-24, 3-40, 3-41, 3-42, and 3-43) is presented in a manner that facilitates identifying the maximum measured concentration at different depths to make the comparison with the action levels.

### **7.2.1 Summary of Performance Assessment and Composite Analysis Source Monitoring**

Source monitoring to support the PA and CA has focused on releases of tritium and C-14 from beryllium block disposals. The Beryllium Source Monitoring Project has produced a useful record of tritium concentrations in the subsurface and atmosphere. Some of the results and methods developed for beryllium source monitoring may be used to find other beryllium disposal locations for the early risk-reduction project. It is evident that long-term monitoring is required to adequately represent the conditions around the buried beryllium. Air concentration data show consistent annual fluctuations, yet there is no obvious long-term trend in air concentrations. The tritium concentration in soil gas has increased at an accelerating rate, and although the concentration must reach a peak and eventually decline, there is no evidence of a peak yet.

Other source-monitoring projects were established to characterize C-14 releases from activated stainless steel and the subsurface conditions in typical disposal pits. The first sampling for the Activated Steel Monitoring Project was conducted in FY 2002, and, as expected, it is evident that the C-14 concentrations are substantially lower than the concentrations found around the beryllium blocks. Sampling equipment and instrumentation are being installed in the active pit, but no data will be available until the equipment and waste have been covered.

### **7.2.2 Summary of Performance Assessment and Composite Analysis Vadose Zone Monitoring Summary**

The vadose zone in the vicinity of the RWMC contains a network of suction lysimeters that allows repeated soil-moisture sampling from soil surrounding the waste and from interbeds in the vadose zone. Data were summarized for the PA and CA radionuclides of interest (i.e., C-14, Cl-36, I-129, Np-237, U-233/234, and U-238). Tritium also was included, because it is a good early indicator for contaminant movement. Maximum concentrations detected were presented for each FY since 1997 and for each depth interval within the vadose zone: shallow (0–11 m [0–35 ft]), intermediate (11–43 m [35–140 ft]), and deep (greater than 43 m [140 ft]). As shown in Table 7-1, data for C-14, tritium, I-129, and uranium are available starting in FY 1997. Data for Cl-36 and Np-237 were not collected until years later. Vadose zone analyses for Np-237 began in FY 2000, and Cl-36 was added to the lysimeter analyte list in FY 2002. The first Cl-36 samples from the vadose zone were analyzed in FY 2003.

In FY 2004, lysimeter sampling results were obtained for all of the PA and CA radionuclides of concern. Iodine-129 and Np-237 were not detected in any of the samples. The maximum concentration of C-14 (4,350 pCi/L) was found in the shallow vadose zone. Maximum C-14 concentrations further from the source term (39 and 185 pCi/L, found at 11–43 m [35–140 ft] and deeper than 43 m [140 ft] bls, respectively) were one to two orders of magnitude less than the aquifer MCL (2,000 pCi/L). Chlorine-36 was detected at low levels in the shallow and intermediate vadose zone with maximum concentrations (up to 32 pCi/L), which is much less than the 700-pCi/L aquifer MCL. Tritium was present in samples from the shallow and intermediate vadose zone and also was present at depths below 43 m (140 ft). Maximum concentrations of tritium were up to an order of magnitude smaller than the MCL of 20,000. Uranium concentrations have been, and continue to be, detected above background for U-233/234 (3.5 pCi/L) and U-238 (1.8 pCi/L) in several lysimeters in the shallow and intermediate vadose zone. In the deep vadose zone, the maximum concentrations for U-233/234 are at about background levels while the maximum concentration for U-238 (3.3 pCi/L) was about twice background levels.

Table 7-1. Summary of radionuclide detections in vadose zone soil-moisture and perched water samples from the Radioactive Waste Management Complex from Fiscal Years 1997–2004.

Sampling Depth Range (ft bls)	Fiscal Year <sup>a</sup>	C-14	Cl-36	tritium	I-129	Np-237	U-233/ 234	U-238
Number of Detection Results/Number of Samples								
Lysimeters 0–35 ft	1997	4/17	NA	13/29	0/20	NA	2/2	2/2
	1998	1/9	NA	3/8	0/7	NA	23/24	24/24
	1999	2/11	NA	3/7	2/9	NA	25/25	25/25
	2000	0/21	NA	3/12	1/18	0/20	62/62	63/63
	2001	NA	NA	NA	NA	0/8	8/8	7/7
	2002	NA	NA	NA	NA	0/5	5/5	5/5
	2003	0/15	3/22	2/7	0/3	0/10	24/24	22/24
	2004	2/28	2/21	10/20	0/13	0/13	22/23	21/23
Lysimeters 35–140 ft	1997	0/1	NA	0/1	0/1	NA	3/3	3/3
	1998	0/5	NA	2/6	0/4	NA	11/11	8/8
	1999	NA	NA	1/1	NA	NA	2/2	5/5
	2000	NA	NA	NA	NA	0/11	18/21	19/20
	2001	NA	NA	NA	NA	0/5	5/5	3
	2002	0/1	NA	NA	NA	0/3	2/3	2/3
	2003	1/15	2/36	4/11	0/4	0/23	33/40	30/40
	2004	2/37	2/35	12/34	0/13	0/11	26/35	21/35
Lysimeters >140 ft	1997	NA	NA	NA	NA	NA	NA	NA
	1998	NA	NA	NA	NA	NA	NA	NA
	1999	NA	NA	NA	NA	NA	NA	NA
	2000	NA	NA	NA	NA	0/2	0/1	0/1
	2001	NA	NA	NA	NA	0/1	0/1	0/1
	2002	NA	NA	NA	NA	0/4	3/3	0/3
	2003	0/6	0/12	0/2	0/1	0/10	6/17	3/17
	2004	0/51	0/33	7/43	0/20	0/15	20/49	12/49
Perched water wells >140 ft	1997	2/2	NA	3/5	0/2	NA	NA	NA
	1998	3/4	NA	3/3	0/3	NA	1/2	1/2
	1999	0/2	NA	0/2	0/3	NA	4/6	2/7
	2000	NA	NA	0/1	0/1	0/1	4/6	4/6
	2001	1/1	NA	NA	NA	0/1	0/1	0/1
	2002	NA	NA	0/1	0/1	0/1	1/1	1/2
	2003	0/2	1/5	0/1	0/1	0/3	5/5	4/5
	2004	1/9	0/6	6/7	0/4	0/2	4/9	1/9

a. Fiscal year spans from October 1 to September 30 (e.g., FY 1997 is October 1, 1996, to September 30, 1997).  
FY = fiscal year  
NA = not analyzed



### 7.2.3 Summary of Performance Assessment and Composite Analysis Aquifer Monitoring

Groundwater monitoring of the network of monitoring wells located around the RWMC has been ongoing for many years. Groundwater samples have been collected on a quarterly basis as required for the OU 7-13/14 routine monitoring program, but this changed to semiannual collections in 2004. Data for tritium, C-14, and I-129 were summarized beginning in FY 1997 (see Table 7-2). Aquifer sampling for uranium was conducted from FY 1998 through the present, while Np-237 data were not collected until FY 1999. Aquifer sampling for Cl-36 began in FY 2001 in the vicinity of the RWMC.

Table 7-2. Summary of aquifer sampling results for radionuclides at the Radioactive Waste Management Complex from Fiscal Year 1997–2004.

Fiscal Year <sup>a</sup>	C-14	Cl-36	Tritium	I-129	Np-237	U-233/234	U-238
Number of Detection Results/Total Environmental Samples							
1997	0/7	NA	10/24	1/8	NA	NA	NA
1998	2/23	NA	18/52	2/24	NA	18/18	18/18
1999	3/31	NA	29/73	1/39	0/47	22/44	33/44
2000	9/46	NA	34/79	0/53	0/55	52/53	53/53
2001	5/49	0/15	23/65	0/54	0/62	62/63	63/63
2002	3/45	0/9	20/43	0/53	3/48	46/46	46/46
2003	0/63	NA	28/64	0/78	0/63	63/63	63/63
2004	0/43	0/44	3/37	0/48	1/44	47/49	47/49

a. Fiscal year spans from October 1 to September 30 (e.g., FY 1997 is October 1, 1996, to September 30, 1997).

FY = fiscal year

NA = not analyzed

Aquifer sampling results in FY 2004 were obtained for all of the PA and CA contaminants of interest (i.e., C-14, Cl-36, I-129, Np-237, U-233/234, and U-238) as well as tritium. Furthermore, C-14, Cl-36, and I-129 were not detected in the aquifer (see Table 7-1). Tritium was found in about one-half of the samples collected in FY 2004. The maximum tritium concentration was 1,370 pCi/L, which is below the aquifer MCL of 20,000 pCi/L. Uranium-233/234 and U-238 were detected in all aquifer samples at levels very close to the normal background concentrations at the RWMC. Upper aquifer background tolerance limits for U-233/234 and U-238 are 1.9 and 0.9 pCi/L, respectively.



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